# PROCEEDINGS OF THE ROYAL SOCIETY OF QUEENSLAND



2020 VOLUME 124

VOLUME 124

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Special thanks are extended to the anonymous referees who reviewed papers submitted for publication in this volume of the *Proceedings*.

2020

# The Royal Society of Queensland

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The Royal Society of Queensland

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## The Royal Society of Queensland

The Royal Society of Queensland has an honourable history as the senior scientific institution in the state. It was established in 1884, with royal patronage continuing unbroken from 1885 to the present time. The Governor of Queensland His Excellency The Honourable Paul de Jersey AC is the present Patron.

The Society seeks to increase respect for intellectual inquiry. It encourages original research and the application of evidence-based method to policy making and decision making. The Society advocates on behalf of science and provides a forum for scientists and lay people to involve themselves in the progress of science in society, with 'science' defined broadly. As a non-partisan, secular, learned society, the Society is committed to the Enlightenment tradition of curiosity-led, knowledge-based enquiry that arguably was born with the Royal Society in London in 1660.

The centrepiece activity of the Society is the production of the annual scientific journal *Proceedings of The Royal Society of Queensland*, supplemented from time to time with Special Issues on specific themes, as these journals of record present Queensland scientific knowledge to the world.

***Proceedings of The Royal Society of Queensland***

The *Proceedings* publishes original scholarship and investigation in natural history relevant to Queensland, including biodiversity, conservation, use, management and economic significance of natural resources. All aspects of the natural sciences, including astronomy, botany, geology, hydrology and zoology, biomedicine, introduced species and dynamic land processes, are considered. The journal will also publish papers on general science, including science-related history, policy, education and philosophy. Papers written from within the social sciences, such as sociology, culture and heritage that deal with the use or management of a natural resource, are welcome.

Following initial appraisal by the Editor, all submitted papers are peer reviewed by a single-blind process (the author's identity is revealed to at least two independent expert reviewers, but the reviewers remain anonymous). The following types of manuscripts are considered:

> Scientific Papers, Short Communications, Historical Reviews, Opinion Pieces, Dissertation Abstracts, Book Reviews.

Authors are urged to follow the instructions given in the *Guide to Authors* which is available on the Society website or from the Honorary Editor. The timeline to allow print publication by the end of each year requires authors to submit papers to the Editor by 1 July.

From Volume 124, articles are being placed online free of charge as they emerge from the editorial and typesetting procedures. Print publication will follow when the volume is completed.

A complete archive of the *Proceedings* with full-text search capability back to 1884, and the preceding three volumes of the *Transactions of the Queensland Philosophical Society* are available online.

## The Royal Society of Queensland Council 2018–2019




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# EDITORIAL FOREWORD

As science in particular and scholarship in general become more reductionist – that is, more specialised – The Royal Society of Queensland is proud to present to a global audience the 124th issue of its annual *Proceedings* as a generalist journal which aims to cross reductionist boundaries and publish knowledge from a range of disciplines generated by authors both within and beyond academe. The three Co-Editors are most pleased that this year's edition features articles on policy, history and taxonomy as well as traditional observation-based natural science.

The Co-Editors thank the authors, anonymous reviewers and Dr Diogenes Antille, who commenced in the editorial role but was unable to continue, for their labours in bringing these articles to maturity. We particularly acknowledge the patience of authors as the review process was prolonged beyond our normal schedule – which is print-publication by 31 December. Not least of the reasons for the delay is the ambitious work program that the Society has tackled in 2019 – four themed Special Issues have been on foot concurrently with this general annual edition.

Another reason is that some papers required substantial deliberation between the Co-Editors, authors and reviewers, testament to the painstaking attention that authors and reviewers give to ensuring that their work is as authoritative and error-free as possible.

The Society also records its appreciation of the services of our new typesetter Sunset Publishing Services and new printer One Access of Brisbane who have worked assiduously to assemble the material, including papers with some complex graphics.

This year marks a milestone in that the journal has been published online with free public access as well as in print. Although the revenue from copy fees has been an important source of income for our leanly budgeted Society, this year the principle of open access to scientific knowledge has prevailed over commercial considerations. The new procedure has allowed us to publish articles as soon as they have completed the editorial process, which is a service to authors; and also conduces to a wider distribution among readers who do not have ready access to the journal through their institution's library or other subscription service.

The Society is pleased to be able to expand the sum total of human knowledge by presenting the work of these authors to an Australian and international audience.

Geoff Edwards
Ross Hynes
Revel Pointon
Co-Editors, volume 124

## SCHOLARLY DEBATE INVITED

From 2 December 2019 (Volume 124), articles accepted for the annual *Proceedings of The Royal Society of Queensland* and Special Issues have been published online as they have been finalised, with free public access. The advent of digital scientific publishing means that it also becomes practicable to publish scholarly debate over published articles. The Society welcomes critical responses to articles that have been published in this edition, if addressing matters of scientific substance and expressed in a scholarly manner. Please refer to the *Guide to Authors 2020* for guidance as to style and submit all such responses to the Honorary Editor. All critical responses will be subject to a systematic review process comparable to that undertaken for other submissions.

## COPYRIGHT

## CONTENTS

# GIVEN CLIMATE CHANGE, WHAT NEXT FOR THE RANGELANDS?

## Presidential Address 2019

EDWARDS, G. P.

The Rangelands Policy Dialogue held on 1, 2 July 2019 was a signature event for the year. The event was co-organised by the Society along with AgForce, the peak representative body for broadacre agriculture, and NRM Regions Queensland, the peak body for the 12 natural resource management (NRM) groups. In this address I would like to present some reflections about the Dialogue and about the future of the Rangelands (broadly defined as the unimproved pastures of inland Queensland), additional to the formal Rangelands Declaration which arose from the conference. I also offer some personal thoughts on the role of the Society as a catalyst for debates of this kind. This opinion piece does not purport to reflect the views of the >120 participants or the Council of the Society.

### SOME REFLECTIONS ON PROCESS

Attendance at the Dialogue was by invitation. The purpose of this was not to exclude any interested parties, but to ensure that all the sectors involved in managing the pastoral lands were represented. (That objective was largely achieved except for the Indigenous perspective. Also, there was no intention to cover the community services sector.) It was not difficult to reach a consensus amongst the diverse participants on a vision for the Rangelands. All parties shared a desire that the pastoral lands be held under the custodianship of land managers who can be sustainably profitable and environmentally sustainable. Attendees from all sectors acknowledged a stake in the welfare of the Rangelands and expressed a desire to upgrade the status and capacity of pastoralists in caring for the land as well as producing food and fibre.

A couple of participants mentioned that it was the first time they had attended a discussion on rural policy that crossed the boundaries between sectoral viewpoints. This was gratifying, although some of the older grey-hairs will recall round-table meetings between scientists, policy officers and practitioners in the 1990s, notably in regard to the Mulga Lands and Desert Uplands. However, the comment is probably an accurate reflection on the absence of contemporary cross-sectoral forums at which solutions to shared challenges can be devised.

A related observation is that there doesn't seem to be any publicly recognisable locus of creative policy formulation focused on rural Queensland, beyond the public service. From the outside, it seems that the Queensland Public Service is preoccupied in clearing the business of the day with little time for reflective thinking about how to meet the challenges of the future.

Deliberative forums are needed not just to clinically analyse condition and trends, challenges and solutions, but to build trust. Several ham-fisted exercises in regulatory change, closing down of focused pastoral management research, withdrawal of rural extension officers and parsimonious funding for the NRM regional bodies have played out down the years into a collapse in trust for the Queensland Government. Government cannot possibly fulfil its role as agent of the public interest unless it enjoys the people's confidence.

Trust takes time to accumulate, not least in conservative rural communities, which may require many years of successful interaction to overcome wariness of knowledge-bearing outsiders. On the other hand, trust can evaporate overnight with a single newspaper headline or broken contract.

The Rangelands Declaration, crystallising a broad consensus of the participants and advocating extensive ongoing consultation, was published on 20 August and is appended here. The Declaration identified a need for new multilateral forums to bring practical knowledge, policy expertise and science together and to build trust. Critically, there was a broadly shared view that the impetus may need to come from outside the public service – "independent of government, but inclusive of it". This is a momentous conclusion. It expresses scepticism that central government nowadays has the capacity to lead Rangelands communities to a different future.

From whom, exactly, is the external impetus to come? One pulse of impetus will surely come with publication of a Special Issue of the Society's *Proceedings*,

a peer-reviewed compilation of papers presented at the Dialogue, being edited as I write by two senior scientist-members, Paul Sattler and Dr Ross Hynes. But more than that will be needed to maintain the momentum that the Dialogue and the Declaration have established.

## SOME REFLECTIONS ON THE ROLE OF THE SOCIETY

In any field, and certainly in rural affairs, there are many expertise-based and membership-based bodies with immense knowledge of the field. But there are not many in any field who can claim all four of content-rich *expertise*, policy *analytical skills*, *independence* of sectoral interest and *freedom from the shackles of economism*. The Society, with its members and its Queensland Science Network, can indeed muster those four capacities, but has traditionally seen its role as presenting knowledge to the world without taking on the more operational toil of building that knowledge into legislation, policy or street-level outreach.

To foster multilateral policy analysis it is necessary to do more than simply publish science, more than explain the implications of the science, and to even go beyond advocating for a policy position based upon the science. Coordinating policy analysis has traditionally been the function of government. To propel the Society into such a role would be a significant departure from its recent tradition, not least because it would require an ongoing commitment of time and treasure over a time-scale of years. For a membership-based organisation which at present is in negative cash flow, this would require external funding, which would inherently place its independence at risk. It would also be a step change in its self-identity.

However, to my knowledge no one has questioned the legitimacy of the Society's role to date in this initiative. Also, taking up policy leadership would not be inconsistent with the role proudly adopted in 1859 when the Society's predecessor, the Queensland Philosophical Society, was established. The first paper it published was on asphyxia, the second on ventilation of buildings. Other early papers covered public sanitation and the water supply for Brisbane. More recently, as our illustrious Life Member Emeritus Professor Ray Specht explained in the Members' Newsletter of August 2018, the Society was involved in the selection of the site for the Mount Coot-tha Botanic Gardens:

> In 1969, … Brisbane Lord Mayor Clem Jones wished to establish the second Botanic Gardens to further the education of the general public … The suggestion to locate the second Botanic Gardens on the Bunya Phyllites below Mt Coot-tha upset the keen rose and camellia societies who wished to locate the new Botanic Gardens on the rich soils at Long Pocket, a site frequently submerged during the Brisbane River floods.
>
> Botanists Selwyn Everist, Len Webb and I, who had been appointed to Clem Jones's Mt Coot-tha Gardens Planning Committee, stressed that most of the home gardens in the Greater Brisbane Area were on Bunya Phyllites. The new Gardens must demonstrate many different ways in which home gardens could be developed:– cactus gardens, scent gardens, rose gardens, ferneries, Japanese gardens, camellia gardens, native flora gardens, 'fossil' gardens, water gardens, and the list continued. Orchard plots of various fruit trees and vegetable gardens would introduce children to the source of these foods. Patches of lawns of different species – that could be walked across – were a valuable teaching experience.

This charming anecdote exemplifies the importance of having a scientific foundation for land-use decisions.

If the Society is to play a prominent role in contemporary policy formulation, some public servants might be discouraged from involvement in the Society's scientific activities and this would weaken its intellectual profile and its collective analytical capacity. Aware of these sensibilities, the organisers of the Rangelands Policy Dialogue announced in advance that public servants were not expected to participate in the final session, when the Declaration was being drafted. The writing team was, however, able to draw upon the senior-level policy experience of several Society members who are retired public servants.

As I was continually reminded during the Dialogue of the capacities of the Society members involved, I became re-convinced that if this initiative is to maintain its momentum and its credibility, then the Society must continue to play the leading role. This is not just professional hubris or pride in the venerable history of the Society; it is based on a recognition that any new regime for managing the pastoral lands must rest on a foundation of scientific knowledge. Those with practical experience, personal opinions and commercial interests of course must be involved in crafting solutions, but an understanding of science and scientific method allows policy to escape the limitations of opinion and interest.

Expressed in other words, Queensland lacks a *theory* or *model* to guide the adjustment that is becoming painfully necessary; and any theory must rely upon knowledge workers, with their sensitivity to the local and global currents of motivating forces.

So much for 'process'; what are we to make of the 'content' of the deliberations?

## SOME REFLECTIONS ON ECONOMIC VIABILITY

What future is there for the Rangelands and how are the people who choose to live there going to transition to a sustainable future? How serious is the widely reported economic distress? After two and a half decades of involvement in Rangelands policy, I still do not have a clear impression of the extent of unprofitability. It is very difficult to form valid conclusions when family accounts are (necessarily) private and enterprises are managed between families; and in any case with high variation from year to year and district to district. The best we can probably do is to look at the graphs of rising debt and conclude that unpaid debt is a symptom of unprofitability. This of course hides success stories of which many were mentioned during the Dialogue; and it downplays the value of optimistic individuals who are proceeding to innovate, to make the best of circumstances and to serve as role models for farmers in their own spheres. The problem with these success stories is that they don't necessarily scale up to the rest of the Rangelands.

The narrative of unprofitability is contradicted by the steady rise in the quantum of funds held in farm management deposits, a tax management instrument by which farmers bank surpluses in good years to offset the poor seasons. Funds held in June 2018 were almost double those held in June 2013.[1] The different trajectories of the two metrics is perhaps an indicator that farmers are segmented between profitable and distressed cohorts.

Participants heard evidence that return on land capital in the pastoral zone is typically low or zero, and this would suggest that a sizeable quantum of the Rangelands debt is unpayable. Even mainstream economics will concede that debt unserviced by reliable cash flow weighs down an enterprise, suffocates innovation, wears out its people and presages eventual bankruptcy. To answer that a debt-laden enterprise can then be taken over by a fresh face is no solution, unless it can be shown that a pathway exists for overcoming previous unprofitability through improved management.

The Dialogue heard economic evidence that macroeconomic policy settings are not congenial to the family enterprise. We could not pursue that theme very far, because the Dialogue was focused on policy settings under control of the Queensland Government. Macroeconomic policy settings such as foreign investment, competition policy, financial regulation and credit policy are under control of the Commonwealth. They deserve forensic analysis and for this reason alone justify taking the Dialogue to a national canvas in collaboration with like-minded bodies.

## SOME REFLECTIONS ON ELEPHANTS

I perceived three elephants in the room. The first is the climate trends and carbon management. We heard that north-western Queensland has the most variable climate on the planet; and that the variability is increasing. This knowledge casts a shadow over all attempts to render enterprises in their current configuration profitable and sustainable. If even intermediate projections of climate change come to pass, pastoralism in its present configuration won't be continuing. In January–February this year, some 600,000 head of cattle in north Queensland perished due to flooding and exposure. There are no indications that the heavy rainfall was simply a once-in-a-hundred-year event, not to be repeated for 99 years. In Naomi Klein's memorable words about climate trends, "This changes everything."

Those who downplay the seriousness of climate change take advantage of humans' natural optimism and eagerness to believe that things won't turn out as badly as projected. In fact, the Intergovernmental Panel on Climate Change (IPCC) was constituted of representatives of government, not science, in order to avoid unnecessary alarmism. Recent statistics indicate that climate is changing faster than the upper bounds forecast by the IPCC; and further, that quite possibly, several tipping points have already been breached. Perhaps the IPCC has not been alarmist enough!

"Given climate change, what next?" The Rangelands Policy Dialogue did not answer the question. I sensed a consensus in the auditorium that business-as-usual could not continue, but as to the remedy,

[1] https://www.anao.gov.au/work/performance-audit/farm-management-deposits-scheme
https://www.theguardian.com/world/2014/mar/25/australian-farmers-hold-321bn-in-farm-management-deposits

participants would probably divide into those who would put their faith in incremental changes; and those who believe that a complete transformation in policy settings and tenure arrangements to manage the Rangelands landscapes will be necessary, or unavoidable.

One participant mentioned on the side that, whereas traditionally in times of drought and particularly poor returns, station wives would encourage their husbands to continue striving, to remain optimistic that good rains and better prices were ahead; nowadays it is the women who want to leave. If this observation is even partly valid, for just a few droughted districts, then the consequences for Rangelands policy are massive. It would be further evidence that the resilience of Rangelands communities is crumbling, as if rows of boarded-up shops in country towns are not evidence enough.

Carbon credits cannot be the saviour. Even on a large scale they won't by themselves build healthy rural communities. First, they require precise and reliable measurement of the carbon being sequestered. In effect this limits them to measurable stocks of carbon such as that embodied in tree trunks. Yet it is not carbon stocks that energise a landscape; it is transitory, labile flows of carbon such as in gaseous form through the soil and through plants, as our member Alan Lauder has lucidly explained in a number of publications. These flows are measurable with sophisticated instruments, but not with the convenience, security and transparency required as a basis for trading. Another way of saying this is that carbon credits are scraps of paper recording promises and are disconnected from biophysical reality. We already know that the markets for food and fibre commodities and for real estate are disconnected from the cost of production; I can't see any happy ending for a regime that relies upon yet another disconnected market. This one could well be conducted in yen or euros by intermediaries with no loyalty to Australia's landholders and no time-horizon longer than the interval required to turn a profit on the exchange.

Scientific evidence indicates that reforestation is the only promising method of sequestering carbon on a scale sufficient to make a conceivable difference to the emissions trajectory; and even then it may not succeed. Pastoralists now yearning for the right to clear native vegetation should understand that the trees are worth more growing or standing than they are flattened. The pioneering era in which native vegetation was seen as an impediment to pastoral production is over.

The second elephant in the room is the decline and, in some cases, the looming collapse of the ecological systems which constitute a healthy landscape. It is not necessary to posit climate change and, in particular, unnecessary to conclude that climate change is anthropogenic: there are many other causes. Soil erosion. Pigs and goats. Leucaena. Prickly Acacia. Feral cats. Buffel Grass. Fires, the absence of fires, unseasonal fires, repeated fires, controlled burning. Vegetation clearing. Myrtle Rust. Overgrazing by domestic stock and macropods to the extent/degree that perennials die. Fragmentation of remnants. Loss of roadside and stock route corridors. Pollution from abandoned mines. Glyphosate. Lippia. Biodiversity loss. Any environmental scientist could make up a longer list within minutes, but the resources committed to these scourges do not remotely conform to any scientific assessment of urgency.

A third elephant, not to my knowledge raised publicly, is the lack of appeal of the inland lifestyle if predictions of hotter or drier weather under climate change turn out to be valid. We cannot conjure up the stoicism and tolerance of hardship of the early pioneers and their families: with modern conveniences now a part of life for nearly everybody of working age, those days have passed into history. Nor will it be sufficient to offer secure, career employment: land managers will need families willing to accompany them. If seemingly endless drought and racks of above-40° days don't discourage families from living and working on the properties, then the dust storms will. Building a workforce willing to repopulate the inland won't be the least of the challenges.

## TENTATIVE CONCLUSIONS

Four tentative conclusions are offered. First, for the Rangelands to be viably managed they need a large increase in human population. The landscape needs labour to manage it. We heard evidence that one million acres in the Wyandra district is under purchase for carbon credits. Vacating these estates will wreak immense damage to the economies and social fabric of Cunnamulla and Charleville, let alone the damage inflicted by uncontrolled pests. Of course, towns everywhere are subject to change, sometimes thriving, sometimes declining. But the people scattered through the pastoral stations depend upon the towns as much as the towns depend upon the businesses operating in their hinterland.

Second, markets cannot reimburse landholders reliably for the costs of managing these landscapes, especially in a period of climate uncertainty. Graziers

are largely price-takers, and the international or national markets in which most of their produce is traded are uninterested in their welfare or the welfare of the land. No amount of trade negotiations, shadow pricing or clean-and-green certification can compensate satisfactorily for the inherent lack of a direct pathway at present for remunerating graziers for the cost of managing their properties.

Third, stewardship payments have considerable potential, being reimbursement for producing a range of goods and services that are not now monetised. They would bring the dignity and sense of purpose that welfare payments, drought aid and other forms of subsidy deny. Some form of public intermediary would be necessary, as would an accreditation system to ensure that the payments would be for proactive restorative action and not simply for abiding by legal restrictions or observing conservative stocking rates. Also necessary would be a profound shift in culture so that landholding families, who for generations have conceived of themselves as producers of commodities, could describe themselves as custodians of a multi-functional landscape producing a range of goods and services, some marketed and some not.

The benefits could accrue not just in financial terms but also in terms of restoration – in reducing emissions, decreasing soil erosion and reinvigorating river systems.

This shift would require a completely restructured regime for remunerating the land managers, deriving from a range of sources. The contemporary lack of adequate public funding of environmental and human infrastructure in the Rangelands, including agricultural colleges, national parks, research stations, Landcare and extension services, does not encourage optimism that a brand-new recipient of public funding will have an easy birth.

Finally – and I stress that this is a personal impression – I doubt whether a land tenure system based largely upon family ownership or leasehold of discrete tracts of land will survive. Certainly, the stations in better condition with low debt load and more reliable rainfall may have a bright future, especially if they can diversify some income streams. I suspect that the properties that are worn down will need to be retrieved by the state or a community land trust to allow restoration and to justify the investment of public money. Pastoral production simply isn't profitable enough to fund the restoration necessary. Much of the complexity involved in administering Landcare grants, drought aid, carbon payments and other forms of subsidy derives from having to justify the expenditure of public money on private enterprises. Those obstacles disappear if the land is owned by the state or a community cooperative. Public ownership would allow the employment of station managers and rangers, offering secure tenure and career employment.

Changes in tenure and management of this gravity would require substantial adjustment, but could be tackled incrementally, that is, property by property as families choose to leave. I emphasise that participation in any such a program must be entirely voluntary.

A precondition to any successful program of restoration of the Rangelands is extensive multilateral dialogue amongst those who share an affection for our Rangelands and who share a determination to build a healthy landscape with healthy rural communities underpinned by policy settings conducive to that vision. I urge the Society and its network of scientists and naturalists to join that mission with relish.

# Declaration for the future of our Rangelands

*Brisbane Dialogue, 2019: a conversation on Queensland's rural future and implications across the Australian outback.*

### In the face of...

→ A deep and enduring attachment to Queensland's outback country, its rural communities, and the iconic ecosystems on which they depend;

→ Ongoing decline in these communities due to unrelenting economic pressures, a legacy of unfortunate planning and legislation, and the lack of bold, forward-looking policy choices;

→ The compounding effects of a highly variable climate that is expected to become hotter and increasingly variable, with more severe episodes of flood and drought, and persistent ecosystem stress; and

→ The resulting vulnerability of production systems to frequent disruption, a widespread decline in land condition, and the tragic loss of biodiversity throughout the ecosystems that sustain us; then

### We, as Queenslanders, need to...

→ Accept there are pressing issues in our Rangelands and an urgency to bring urban and rural communities into serious and constructive conversation;

→ Celebrate our common agreement on the biological, cultural, and economic necessity of a flourishing, populous, and life-affirming outback, while minimising attachment to outdated ideologies that only serve to separate people from one another;

→ Affirm that landscape management properly rests in the hands of people acting with modern knowledge and Indigenous wisdom, and that they are the trusted custodians of sustainable utilisation, conservation, and regeneration;

→ Recognise that more investment is required to build the ecological health of our country, including arrangements that deliver stewardship and natural capital payments; therefore,

### We, the undersigned, commit to...

→ Cultivating an enduring and respectful rapport between land managers and the public, enabling fulfilment of mutual rights and obligations;

→ Supporting a Rangelands reform agenda that includes:

- ◆ Reviewing and revitalising institutional arrangements to deliver strengthened regional participation in land use planning, regulation, and conflict resolution;
- ◆ Programs to enable the informed and ethical use of data to ensure all people can participate in shaping the Rangelands future in a constructive manner, particularly in the area of natural capital accounting;
- ◆ Cooperative ownership of a biennial State of the Rangelands Report presenting social, biophysical, cultural, and economic indicators of condition and trend;

→ Establishing a Rangelands Consultative Council, independent of government, but inclusive of it, to improve our institutional capacity for developing and delivering improved governance arrangements and practical management solutions across the Rangelands, for the benefit of the country, its rural communities, and for Australia's current and future generations.

*20 August, 2019*

The Royal Society of Queensland | AgForce Queensland | NRM Regions Queensland

# THE ECOLOGY OF GNAMMAS (WEATHERING PITS) ON THE STANTHORPE PLATEAU, NORTHERN NEW ENGLAND TABLELANDS, WITH SPECIAL REFERENCE TO THE CLAM SHRIMP *PARALIMNADIA URUKHAI* (WEBB & BELL) (CRUSTACEA: BRANCHIOPODA: SPINICAUDATA)

TIMMS, B. V.[1], BOOTH, C. J.[2], NEWMAN, M.[3] & McCANN, J. A.[1]

The exposed granites of the Stanthorpe Plateau are pitted with shallow rock hollows known as pan gnammas. Most are <7 cm deep, much shallower than gnammas studied elsewhere in Australia. With a total of 35 aquatic invertebrate taxa, averaging 5.6 taxa per gnamma, they also host a less diverse invertebrate fauna than other Australian gnamma groups. Their species richness per inselberg is only about one-quarter of that in the Wheatbelt (WA) and less than half that on the Eyre Peninsula (SA) and in Central Victoria. Gnamma depth, as a surrogate for hydroperiod, is likely to play a significant role in determining biotic diversity in pan gnammas, as shown by a strong correlation between species richness and gnamma depth. The relative shallowness of the Stanthorpe Plateau gnammas is due to a different mode of formation, with rock dissolution occurring mainly at the air–water–rock interface at the gnamma edges, resulting in vertical C-shaped edges and sideways spread rather than deepening. The invertebrate metacommunity of Stanthorpe Plateau gnammas consists mainly of dipterans and crustaceans, of which 14% are gnamma obligates. We documented the life cycle of the clam shrimp *Paralimnadia urukhai*, endemic to gnammas on the northern New England Tablelands. Sixteen months of monitoring populations in one of the deepest Stanthorpe Plateau gnammas (7.5 cm) illustrates the constraints imposed by short hydroperiods, with only one of eight hydroperiods resulting in significant reproduction and the others resulting in probable egg bank depletion, or non-hatching in one case, due to low temperatures. Rough calculations of egg production and hatching suggest the population is presently sustainable, but future climatic changes could restrict clam shrimps to deeper gnammas, which are scarce on the Stanthorpe Plateau.

Keywords: Aquatic invertebrates, hydroperiod, biogeography, biodiversity

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## INTRODUCTION

Exposed granitic rocks throughout the world develop weathering pits over time due to rock dissolution (Twidale & Vidal-Romani, 1998; Migoń, 2006). In Australia these are called 'gnammas' (Twidale & Corbin, 1963; Bayly, 2011). Gnammas come in many forms due to different weathering scenarios and lithologies – two basic forms are shallow petri dish-like 'pan gnammas' and deeper 'pit gnammas' (Timms, 2012a,b, 2013a, 2017).

Pit gnammas harbour a fauna somewhat similar to that in small ponds (Timms, 2014a,b), but the much shallower pan gnammas, against intuition, often support a more diverse and specially adapted fauna (Pinder et al., 2000; Timms, 2012a,b). Pan gnammas present a challenging environment for life due to their shallowness, short hydroperiods, clear waters and geographic isolation. Generally, they support specially adapted chironomids and ceratopogonids, clam shrimps, fairy shrimps, and an array of smaller cladocerans, ostracods, copepods and insects, many of which are restricted to gnammas. In south-western Australia the gnamma fauna is the most diverse in the world (Pinder et al., 2000; Brendonck et al., 2017) with a particularly large array of endemic ostracods and cladocerans, and several large branchiopods (Pinder et al., 2000; Timms, 2012a,b). Diversity and endemism are much lower in southern and eastern Australia. Some species are shared across the continent and others are more localised, especially the crustaceans (Timms, 2017). There are at least 50 endemic species in gnammas of the Western Australian Wheatbelt (Pinder et al., 2000), but only five in Eyre Peninsula gnammas (Timms,

2014); and apparently one each in Central Victorian and Stanthorpe Plateau gnammas, though a few other endemic species are shared between adjacent states (Timms, 2012a,b, 2014, 2017).

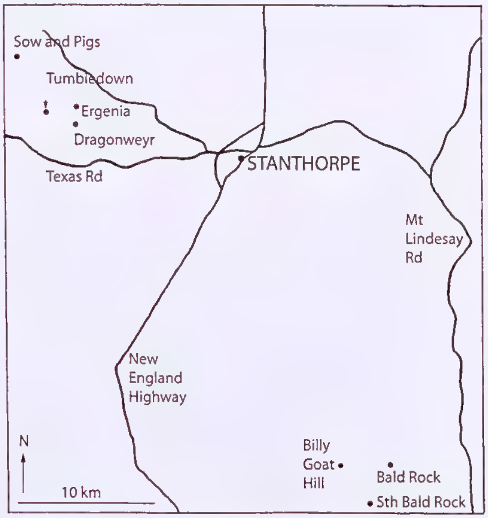
The existence of gnammas in the granites of the Stanthorpe area in Queensland has been known for a long time, and the clam shrimp *Paralimnadia urukhai* (Webb & Bell, 1979) characteristic of these pools was described 40 years ago (Timms, 2016). *Paralimnadia urukhai* is possibly a species complex (Schwentner et al., 2015) and is restricted to pan gnammas in the far northern New England Tablelands bioregion. Other components of the fauna of these pools were not known. We investigated the invertebrate communities of these pools and attempt to explain their particularly low diversity in terms of the distinctive geomorphology and hydrology of the gnammas. The clam shrimp *P. urukhai* – being the only crustacean in the pools large enough to monitor – was a major focus of this study. Although it is generally well adapted for life in temporary habitats, the peculiarities of rainfall patterns on the Stanthorpe Plateau impose added stress on its life cycle.

## MATERIALS AND METHODS

### *The Sites*

The study area is intrusive granite country on the Stanthorpe Plateau, a subregion in the far northern New England Tablelands (Department of the Environment, 2013) in the Queensland/New South Wales border area (Figure 1). Although this area has few discrete inselbergs, sites where gnammas are often most common (Twidale & Corbin, 1963), there are many exposures of granite flat enough for gnamma development. However, locating gnammas is difficult as none are marked on maps and they are mostly too small to be seen on Google Earth. More than 40 were found by searching granite outcrops, and 26 were chosen for this study on the basis of being accessible and large enough to retain water for many weeks. Bald Rock and South Bald Rock in New South Wales have one gnamma each near their summits, both part of this study. Girraween National Park in Queensland features several gnammas on rocky outcrops, particularly on flat hilltops, of which four easily accessible ones were chosen. Many gnammas occur on small granite outcrops on private land to the west of Stanthorpe. Ten were chosen on the Sow and Pigs outcrop (a local name for an outcrop near Amiens), and ten in the Greenlands area (two on Dragonweyr, three on Tumbledown, five near the Egernia/Tumbledown property boundary).

FIGURE 1. Map of Stanthorpe area showing the locations of the studied gnammas groups




### *Mapping Methods*

Three representative sites (Dragonweyr, Egernia/Tumbledown and Billy Goat Hill) were mapped. Contour maps were generated from high-resolution (5 mm pixel size) digital surface models. These were generated using structure from motion in commercial image-processing software (Pix4Dmapper Pro version 4.1.19). Photographs were taken from a drone, either an Autel X-Star Premium or a Phantom Professional 3 flying at a maximum of 10 m above ground with a standard camera setup of a 12 MP camera with a fixed lens and focal length, mounted to the drone with a gimbal (stabilising unit).

### *Sampling Methods*

To thoroughly assess the fauna, each site was sampled five times over 2–3 years during inundation, a protocol proven in previous gnamma studies to be sufficient for species accumulation curves to plateau (Timms, 2014). The gnammas at Sow and Pigs were studied during 2008 and 2009, and the remainder from 2016 to 2018. Visits were timed to be about 2 weeks after rain events, when the gnammas were most likely to be inundated. On each occasion, a water sample was taken from each pool to determine conductivity (μS/cm), using an ADWA332 conductivity meter; and turbidity, using a Secchi disc tube calibrated in Nephelometric Turbidity Units (NTU). This tube does not measure turbidity lower than 5 NTU, so is not precise for very clear

waters. In the Dragonweyr 1 gnamma, water temperatures were measured with an Anritherm thermocouple thermometer accurate to ±1°C, and pH with a Hanna pHepR4 meter. Percentage organic matter content of many (but not all pools) was measured using a Ceramic Engineering CEMLS muffle furnace. Pool depths and areas were measured when pools were full, with a tape measure or, for Dragonweyr 1 and Billy Goat Hill gnammas, ascertained from contour mapping. The volumes were calculated using the formula $V = \pi r^2 z$, where $V$ = volume, $r$ = average radius determined from length and width measurements, and $z$ = depth. Gnamma depths were used as a surrogate for hydroperiod (e.g. Anusa et al., 2017; Vanschoenwinkel et al., 2008).

Macroscopic plants and microscopic phytoplankton were rarely seen and were not sampled or identified to species. The meiofauna was sampled by sweeping a small plankton net (opening 10 cm × 8 cm, bag length 50 cm, net mesh 159 µm) through the water for one minute. The bottom sediment was stirred a little in order to catch benthic as well as planktonic species. Microfauna smaller than 160 µm were not examined. The meiofauna were preserved in 70% ethanol for later study. Macroinvertebrates were caught by sweeping a household sieve (12 cm diameter, 1 mm mesh) through the water for a total of 2 minutes in sweeps each lasting 20–40 seconds. Experimental sweeps for shorter and longer periods had shown that 80–90% of macroinvertebrate species present were caught within 2 minutes. Macroinvertebrates were sorted alive in a white tray, and representatives of all taxa caught were preserved in alcohol for later identification. The remainder were returned alive to the pools, together with all tadpoles caught. The abundance of each taxon was estimated on a log scale – the macroinvertebrates from numbers seen in the sorting trays in the field, and the meiofauna from numbers seen in petri dishes under a microscope. Similar field protocols have been used in comparative studies of gnammas across Australia (Timms, 2012a,b, 2014a, 2017). Permits were held for collecting in the Girraween and Bald Rock National Parks.

### *Studies on* Paralimnadia urukhai

The life cycle of *Paralimnadia urukhai* was studied in the Dragonweyr 1 gnamma. This was the deepest (7.5 cm) of all pools found on private property. The pool was monitored daily to fortnightly after each rain event from 26 April 2017 to 25 August 2018. Daily rainfall was measured at a residence ca. 100 m away. Pool depth was measured on each visit on a scale installed for the purpose. During cold periods, observations were made during the late morning to early afternoon, when it was warm enough for shrimp to become active after overnighting in the sediments, but summer observations could be made as early as 9 am. When the shrimp were large enough to be seen by naked eye (~3 mm, 1–2 weeks after hatching), the gnamma was divided into smaller areas with long poles and the shrimp counted three times. When the shrimp were smaller, numbers were estimated by taking 20 water samples of 500 ml each, pouring the water through a 1 mm mesh sieve, counting shrimp through a hand lens, taking the median sample number, and calculating the total based on the proportion of the pool volume sampled. Mate-guarding pairs were far less numerous and were accurately counted, again after dividing the pool with long poles. For measuring shrimp carapace lengths, >30 were caught with a sieve, free water was removed to reduce flash reflections, and they were photographed individually using a purpose-built focus rail with an EF 100 mm USM macro lens set to 1:1, a Raynox m 250 attachment and a Canon Flash Macro Ring Lite MR-14EXII. Shrimp were returned alive to the pool, and their images were saved as JPEG files and measured against a previously calibrated scale. Accuracy was ±0.1 mm. Eggs at different stages of development within the carapace were evident in photos.

A separate study was done during 2017 on the shrimp in the large gnamma on Billy Goat Hill in Girraween National Park, because of the pool's relatively long hydroperiod. Six visits were made at 1- to 2-month intervals from March to November. Depth and water conductivity were measured, and shrimp were collected and preserved. Each time, 30 shrimp were measured under a low-power microscope with an accuracy of ±0.1 mm. This pool had a large population of shrimp (>5000), so permanent removal of 30 shrimp each visit would not have significantly depleted the population.

### *Statistics*

To test questions of faunal relationships between these groups of gnammas and other gnammas across Australia assessed by the first author (Timms, 2012a,b, 2014a, 2017), we conducted multivariate analyses using PRIMER (v6) (Clarke & Gorley, 2006). The Stanthorpe gnammas were treated individually in one analysis, then were considered in three sets and compared with nine other sets of gnammas across Australia. In both analyses, non-metric multidimensional scaling (NMDS) ordination was

performed to visualise patterns in assemblage composition among the data sets. In the first analysis, the physical parameters of gnammas were added to the ordination. In the second analysis, the relationships between 12 groups of gnammas across Australia in the Wheatbelt (south-west WA), Eyre Peninsula (SA) and central Victoria were explored.

## RESULTS

### *Physicochemical Features of Gnammas*

Pan gnammas occur on many flat or gently sloping granite exposures. Most on the Stanthorpe Plateau are 3–7 $m^2$ in area and 3–8 cm deep (Table 1). While some are roughly circular or roughly oval (e.g. Dragonwyer #1, Figure 2), many are of irregular shape (e.g. Egernia/Tumbledown sites, shown in Figure 3). All have edges C-shaped in profile or occasionally B-shaped with the upper level abandoned, except for the Billy Goat Hill gnamma, which has even and steeply sloping sides (Figure 4). No laminations were observed in surficial rocks, though the surface was irregular at many sites such as Egernia/Tumbledown (Figure 3).

Rainfall at Stanthorpe was 746 mm in 2015, 798 mm in 2016, and 785 mm in 2017. The long-term annual average is 767 mm, and much of the summer rainfall comes in discrete storms (BOM, 2018). The rainfall recorded at Dragonweyr for the 12 months from 26 April 2017 (the first inundation monitored) to 25 April 2018 totalled 709 mm (about 8% less than the annual Stanthorpe average). Rainfall during the following winter, from 26 April to 25 August, a drought period, was 98 mm (about 46% less than the long-term Stanthorpe average). Average evaporation rates are higher than average rainfall each month.

TABLE 1. Salient physicochemical features of the Stanthorpe gnammas

| | **Sow and Pigs** | **Egernia/ Tumbledown** | **Tumbledown** | **Dragonweyr** | **Bald Rock** | **Billy Goat Hill** |
|---|---|---|---|---|---|---|
| Number of gnammas | 10 | 5 | 3 | 2 | 5 | 1 |
| Altitude (m asl) | ca. 835 | ca. 888 | ca. 880 | ca. 906 | 1162–1210 | 1082 |
| Mean area ($m^2 \pm$ SE) | 3.6 ± 1.5 | 23.1 ± 9.2* | 3.8 ± 3.1 | 5.4 ± 3.1 | 6.6 ± 2.9 | 16.3 |
| Mean max. depths (cm ± SE) | 5.2 ± 0.9 | 4.5 ± 0.5 | 6.3 ± 0.3 | 6.5 ± 0.2 | 7.4 ± 0.5 | 20 |
| Mean conductivities (µS/cm ± SE) | n.d. | 36.4 ± 6.1 | 53.0 ± 8.1 | 78.2 ± 10.2 | 68.5 ± 8.3 | 87 ± 11.1 |
| pH range | n.d. | 5.3–5.6 | n.d. | 5.1–6.3‡ | n.d. | 5.0–6.1‡ |
| Mean turbidities (NTU ± SE) | n.d. | 12.5 ± 2.1 | 14.3 ± 3.3 | 15.0 ± 2.8 | 8.9 ± 2.2 | 20.5 ± 6.8 |
| Mean % organic matter in bottom mud | n.d. | 3.1 ± 0.3 | n.d. | 2.8 ± 0.2 | 16.2 ± 9.4† | 14.6 |

* One site much bigger (38 $m^2$) than others (<5 $m^2$).
† One site with much organic matter (44%), others <8.6%.
‡ Daily range.

Water depth in the Dragonweyr #1 gnamma reflected variability in rainfall and evaporation. In winter 2017 the depths remained steady for long periods except for one near-drying event (Figure 5d), but in the drought winter of 2018 the gnamma was dry the vast majority of the time. The summer 2017–18 depths fluctuated widely due to heavy storms and daily evaporation rates exceeding 9 mm at times (Figure 6d). The deeper Billy Goat Hill pond fluctuated less, though greater variability would probably have been recorded if it had been visited more regularly.

Most conductivity measurements were lower than 100 µS/cm (Table 1), though drying deeper pools sometimes recorded values to 342 µS/cm. Waters were always acidic, and pH fluctuated daily in those pools for which data are available (Table 1). Pool waters were generally clear (<20 NTU) and bottom sediments were low in organic matter content (<3%), except in pools in forests (four of the five Bald Rock sites), which had much higher levels (Table 1).

In the seasonal study of Dragonweyr 1, water temperatures were only noted when the shrimp were monitored, so daily and seasonal extremes were not recorded. The 'winter' (May–August 2017) average

for sampling was 21.3°C, and the 'summer' (October 2017–March 2018) average was 25.6°C. Daily values varied widely according to prevailing weather and were typically 3–4 degrees higher than the air temperature. For the only winter 2018 filling, air temperatures (recorded by the Bureau of Meteorology for Stanthorpe) ranged from 14.2°C to 19°C and were probably colder locally.

FIGURE 2. Dragonweyr #1 gnamma (a) map (contour interval 5 cm) and (b) aerial photo

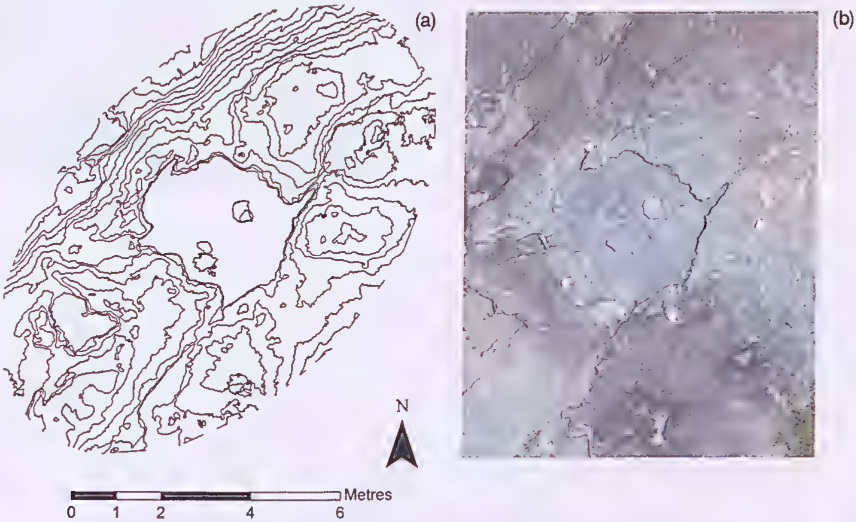



FIGURE 3. Ergenia/Tumbledown gnammas from the air

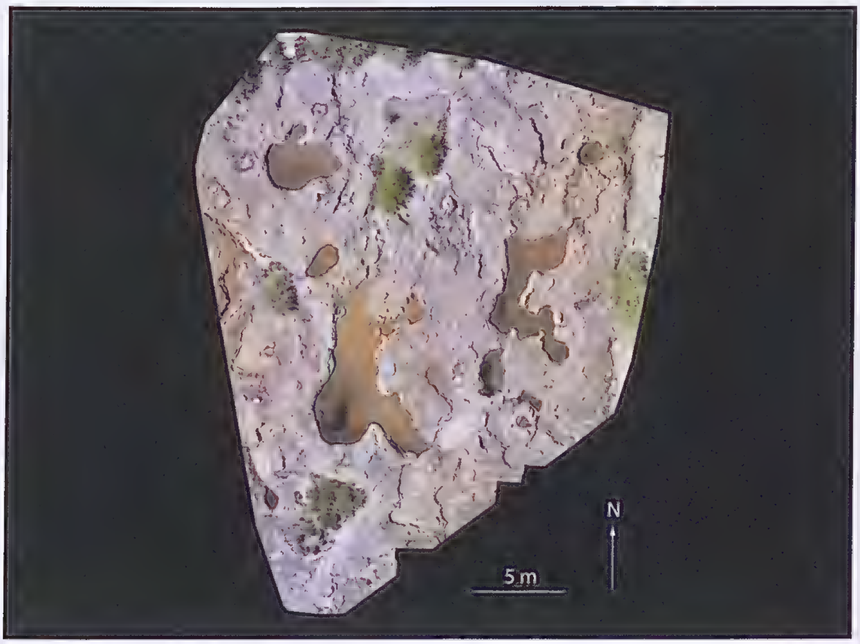
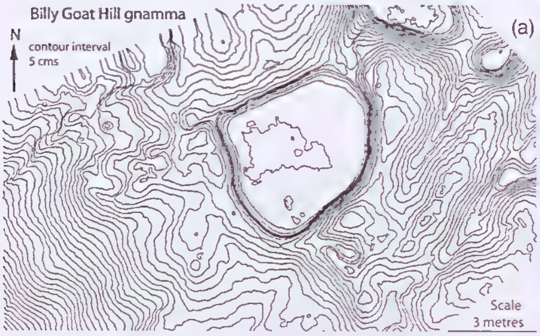
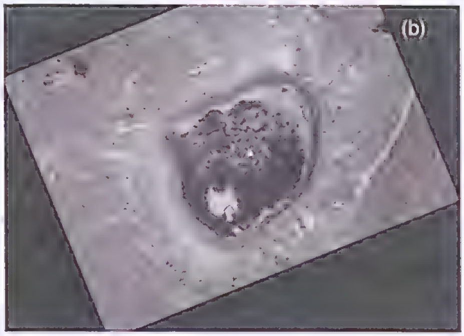


FIGURE 4. Billy Goat Hill gnamma (a) map (contour interval 5 cm) and (b) aerial photo




*Gnamma Flora*

The only multicellular species of plant seen in the Stanthorpe Plateau gnammas was *Isoetes* sp. in two gnammas, at Egenia and Tumbledown, sprouting as the gnamma dried. There were sometimes blooms of chrysophyte algae (golden algae) in the Greenlands gnammas, but no blooms of chlorophytes or cyanobacteria were recorded anywhere. Chlorophytes were often seen growing on shrimp limbs.

*Gnamma Fauna*

Thirty-five taxa were recorded in the 26 gnammas, though most gnammas supported only a small subset. Alpha diversity (momentary species richness) ranged from 4.0 to 8.1 mean values in five groups, and beta diversity (cumulative species richness, CSR) varied from 5.2 to 12.4 (Table 2). The CSR correlated positively with gnamma depth ($r$ = 0.9354, $n$ = 26); this relationship is expressed visually in Figure 7 by a bubble MDS ordination in which pool size overrides any district differences. The relationship is affected by two of the deepest sites (Bald Rock #2, BGH) also having the most organic matter and detritus, which could have also contributed to their enhanced diversity. Cladocerans and ostracods were found mainly in pools with higher apparent amounts of organic matter, but this could not be tested statistically due to incomplete data on benthic organic matter.

TABLE 2. Species richness in the Stanthorpe gnammas

| | Sow and Pigs mean ± SE | Egernia/ Tumbledown mean ± SE | Tumbledown & Dragonweyr mean ± SE | Bald Rock mean ± SE | Billy Goat Hill mean ± SE |
|---|---|---|---|---|---|
| Momentary SR | 4.0 ± 0.4 | 5.5 ± 0.3 | 5.6 ± 0.4 | 8.1 ± 0.5 | 11.9 ± 0.3 |
| Cumulative SR | 5.2 ± 0.6 | 7.8 ± 0.4 | 8.8 ± 0.4 | 12.4 ± 0.7 | 28 |

Overall taxonomic composition was 22 insects, eight crustaceans, and five others (Appendix). The chironomid *Paraborniella tonnoiri* (Freeman, 1961), the ceratopogonid *Dasyhelea* sp. and the mosquito *Aedes rubrithorax* occurred at each site, commonly in large numbers. The clam shrimp *Paralimnadia urukhai*, the small beetle *Sternopriscus multimaculatus* (Clarke, 1862) and an unidentified planarian occurred at most sites (57–73%), while the cladoceran *Armatalona imitatoria* (Smirnov, 1989) and an unidentified nematode were found at many sites (35%). Microcrustaceans included two cladocerans, two ostracods and a copepod, none common except *A. imitatoria* (Appendix). Many species such as the gastropod *Isidorella hainesii* (Tryon, 1866) and a variety of beetles and hemipterans were found only in the large Billy Goat Hill gnamma. Some species occurred at most sites within a subgroup but were rare or absent elsewhere, such as the bryozoan *Hyalinella* sp. found in the Egernia/Tumbledown and Bald Rock gnammas, and the ostracod *Cypretta* n. sp. at the Bald Rock sites. Just two species are known to be endemic to the Stanthorpe gnammas, *Paralimnadia urukhai* and *Anthalona* n. sp., while the two undescribed ostracods may be the same as new ostracods collected by the first author in Central Victorian gnammas, or the *Ilyodromus* could be new and not previously recorded, given short-range endemics in WA (S. Halse, pers. comm.; Shearn et al., 2018).

FIGURE 5. Dragonweyr #1 gnamma in winter 2017, relationships between (a) daily rainfall, water depth, (b) clam shrimp average sizes, (c) number of mate-guarding pairs, and (d) total clam shrimp numbers

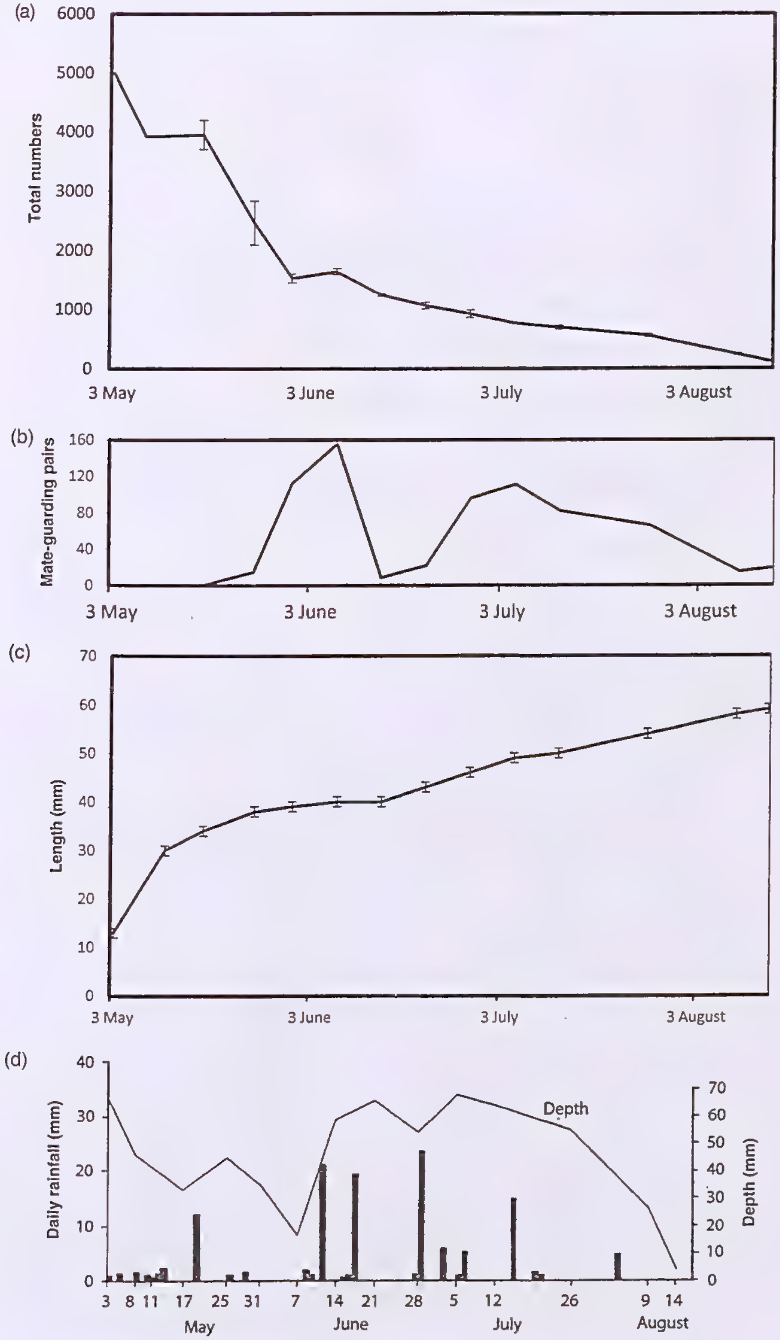


FIGURE 6. Dragonweyr #1 gnamma in summer 2017–18, relationships between (a) daily rainfall, water depth, (b) clam shrimp average sizes, (c) number of mate-guarding pairs, and (d) total clam shrimp numbers

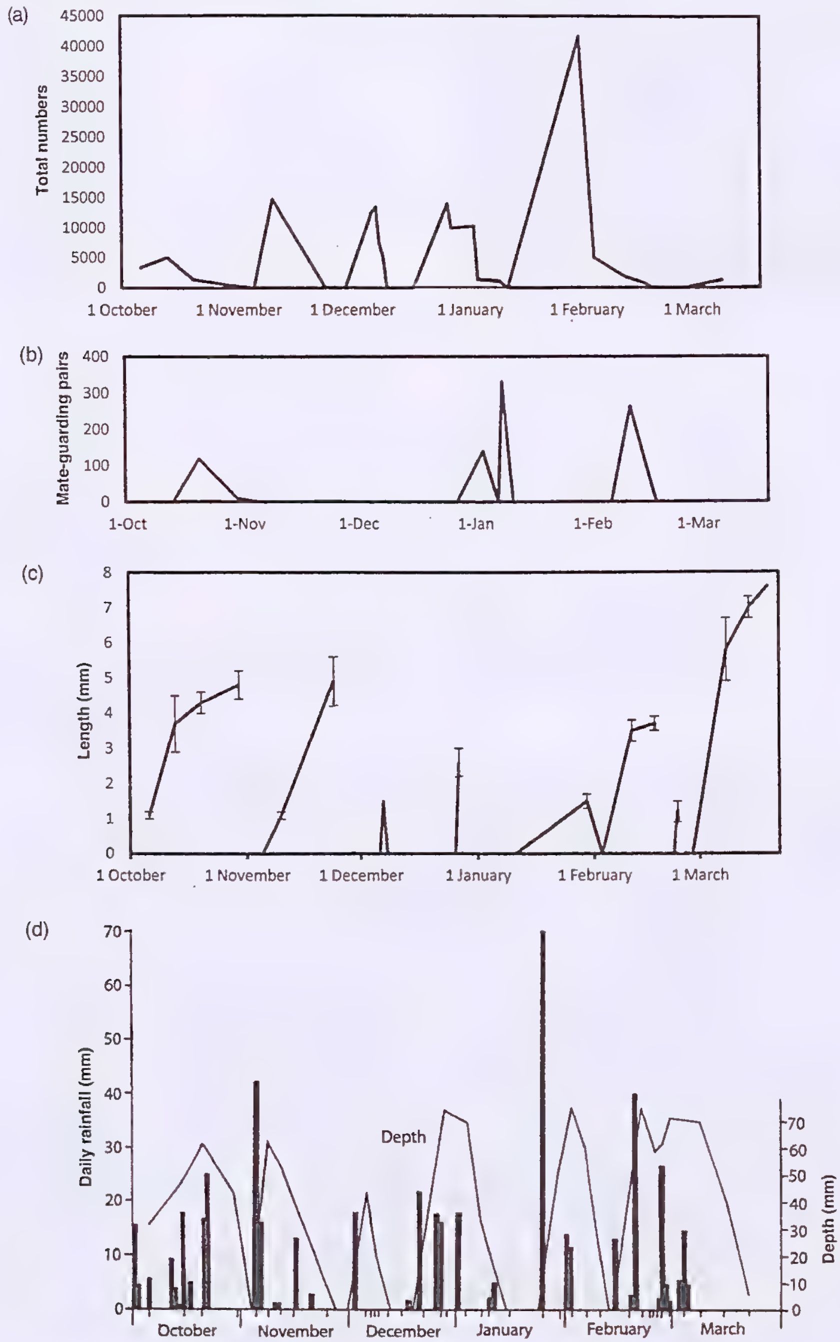
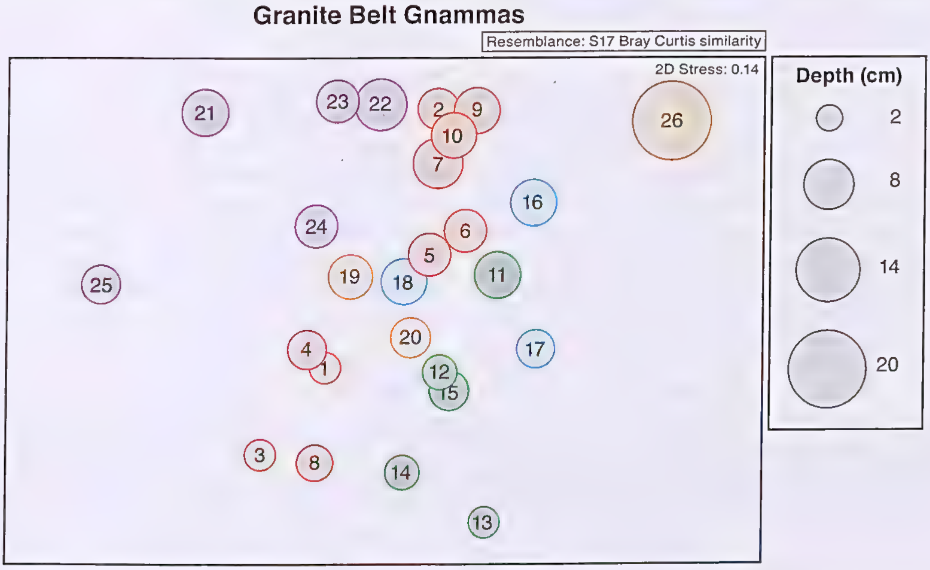


FIGURE 7. Ordination of the 26 Stanthorpe gnammas (1–10 Sow and Pigs, 11–15 Egenia/Tumbledown, 16–18 Tumbledown, 19–20 Dragonweyr, 21–25 Bald Rock, 26 Billy Goat Hill). Circle sizes proportional to maximum depth of the gnammas.




*Life Cycle of* Paralimnadia urukhai *in Dragonweyr 1 Gnamma*

Dragonweyr 1 is the deepest of the pools at Greenlands and hence the one most likely to retain water. When full, it is 7.5 cm deep and has an area of 7.4 m$^2$ and a volume of 590 L (Figure 2).

The first cycle completely studied – in response to 41 mm of rain on 26 April 2017 – persisted through winter until mid-August (almost 16 weeks), during which an additional 133 mm fell in mostly small rain events. Shrimp grew rapidly in the first two weeks, then slowly increased in size to a maximum average length of 5.9 mm. The population decreased rapidly in the first month, then slowly over time (Figure 5), and was severely stressed (as indicated by a lack of mate guarding in a dioecious species; Benvenuto et al., 2009) when the pond became very shallow in mid-June (probably shallower than indicated in Figure 5). The number of mate-guarding pairs recovered by early July, but total numbers and breeding activity (as indicated by the number of mate-guarding pairs) then slowly decreased until mid-August when the pond dried. By this time, at about 3.5 months of age and 6 mm long, the shrimp averaged 9.1 ± 0.2 SE ($n$ = 30) growth lines. Based on what has been observed in other conchostracan species, each growth line on a female shrimp carapace is likely to represent a moulting and a reproductive event (Bishop, 1968; Dobrynina, 2011; Thiery, 1991), though not for the early moults (1–3 in *Paralimnadia stanleyana* (Bishop, 1968a) and 2–3 in our species). Photos of reproductive females showed that carapaces contained ca. 50–120 eggs, though Webb & Bell (1979) reported a maximum of 80. Thus, we can very roughly estimate that 330,000 eggs were produced during cycle 1, based on the following calculation: the estimated number of females halfway through the cycle after reproduction commenced ($n$ = 600) × the median number of eggs per batch ($n$ = 80) × 7 growth lines (disregarding the 2 first non-reproductive moults). However, there are significant caveats to this calculation due to the variability in numbers of eggs produced, the continual death of individuals, and the assumption that females accounted for 50% of the population. Whatever the real figure for winter 2017, there were more than enough eggs produced to maintain the population. None were produced in the winter of 2018.

Life cycles during the warmer months (from October 2017 to April 2018) were very different. Some details are lacking because sampling dates were sometimes too far apart (Figure 6). There were 6 cycles, each lasting from 8 to 34 days. Each commenced 2–3 days after rain and the hatchlings grew rapidly, but in most cycles individuals had time to

grow to only about 4–5 mm before the pond dried. Mate guarding occurred in only 3 cycles, so reproduction was most likely limited to these; but in each of these cases, the guarding occurred almost at the end of the cycle, and examination of some ovigerous females collected at this time suggests their eggs had not yet matured. Cycle 6, which lasted for 30 days, was difficult to interpret, with two hatchings (an estimated two weeks apart), but in small numbers ($n < 200$). The first hatchlings reached 7.6 mm in length and the second cohort 5.6 mm. The numbers hatching in these cycles varied greatly, from approximately 5000 in the first cycle to 15,000 in each of the next three, to 40,000 in the fifth, but only about 200 in the sixth. We estimate that throughout the year roughly 100,000 eggs hatched. These numbers imply that a sizeable surplus of eggs was produced during the year from April 2017 to April 2018.

In the less environmentally variable Billy Goat Hill gnamma, shrimp grew steadily all year, males reaching an average 9.1 mm and females 7.7 mm. They too had an early quick growth period. The 2017 population probably commenced with heavy rain filling the pond on 13 March and persisted till sometime after late November, a duration of at least 8 months. A visit in early January 2018 found shrimp much smaller in length, indicating a new population, so the pond must have dried by December. In this site, females averaged 18.8 ± 0.5 SE ($n = 30$) growth lines by November 2017, indicating roughly 17 reproductive events for each female, but there probably were more (Bishop, 1986a; Dobrynina, 2011; Thiéry, 1991). Without population estimates the number of eggs produced is unknown, but it would have been substantial.

Like most clam shrimps, the *Paralimnadia urukhai* sexes are dimorphic, but this was not taken into account in length measurements. Based on length differences between males and females in the Billy Goat Hill population, the maximum error in length determinations was 5% of the average. The growth rate of the winter population at Dragonweyr 1 averaged 0.045 mm/day, whereas the three summer populations varied between 0.13 and 0.95 mm/day. This is an approximate 10–20 times seasonal difference. However, the summer rates were largely influenced by the length of the hydroperiod, which compromises the comparison because the growth rate varies with age; and with the growth truncated, only the earlier faster growths were measured. The average rate in the Billy Goat Hill population, which incorporated mainly winter growth, was 0.030 mm/day.

## DISCUSSION

### *Stanthorpe Plateau Gnammas and Their Invertebrate Communities*

The gnammas on the Stanthorpe Plateau are mostly not ideal habitats for invertebrates. Like pan gnammas elsewhere, they are ephemeral with seasonally variable hydroperiods and waters that are mostly clear and mildly acidic (Table 1). But these gnammas are shallower than others studied in Australia, and their invertebrate communities are less diverse. We recorded a total of 35 invertebrate taxa in 26 gnammas across four localities (spanning a total distance of about 40 km). Most of these gnammas support only a small subset, averaging 5.6 taxa per pool.

Insects (22 taxa) made up almost two-thirds of the total, and crustaceans (8 taxa) about a quarter. Few taxa are gnamma specialists, and just two of these are endemic or possibly endemic to the northern New England Tablelands. The taxa most widespread on the Stanthorpe Plateau, occurring in all gnammas studied and usually abundant, are three fly (diptera) species (a chironomid, ceratopogonid and mosquito), none of which are restricted to gnammas. Also widespread are a clam shrimp (77% of gnammas), a cladoceran (35%), planarian (58%), a dytiscid beetle (77%), and nematodes (38%) (see full taxa list in Appendix). Only the clam shrimp is a gnamma obligate, though the chironomid and ceratopogonid are characteristic of gnammas (Timms, 2012a,b, 2014, 2017). Many species – including a snail and several beetles and hemipterans, none of them gnamma obligates – are found only in the deepest gnamma (Billy Goat Hill, 20 cm depth), exemplifying the likely influence of depth on diversity, a relationship that emerges very clearly on the Stanthorpe Plateau.

### *A Comparison with Gnamma Fauna Elsewhere in Australia*

South-western Australia has the most diverse gnamma communities in the world, with those in south-eastern Australia more average (Brendonck et al., 2016). The 35 taxa recorded on the Stanthorpe Plateau constitute only one-sixth of the total recorded for the pan gnammas in the Wheatbelt region of south-west Western Australia (Table 3). The average inselberg richness, perhaps a more appropriate level of comparison, on the Stanthorpe Plateau at 16 taxa, is only about one-quarter of that in the Wheatbelt (60) and less than half that on the Eyre Peninsula, South Australia (35) and in Central Victoria (35).

The differences in species richness are particularly pronounced for three crustacean groups that

are highly diverse in the Wheatbelt gnammas: cladocerans (35 species), ostracods (34) and copepods (12) (Pinder et al., 2000). These groups are much less diverse (with about 75% fewer species) on the Eyre Peninsula (nine cladocerans, eight ostracods and one copepod) (Timms, 2014a) and in Central Victoria (ten cladocerans, eight ostracods and three copepods) (Timms, 2017) and highly depauperate (with more than 90% fewer species) on the Stanthorpe Plateau, with just four cladocerans, two ostracods and one copepod. Explaining these differences – the relative influence, for example, of habitat features, dispersal constraints, climatic patterns and extinction histories – is a biogeographic puzzle with many links to questions of island biogeography.

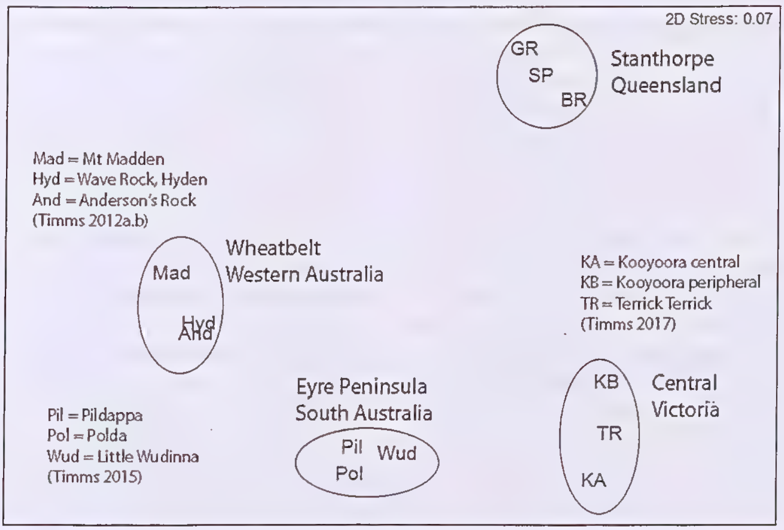
The distinctiveness of the Stanthorpe Plateau gnammas was confirmed in an ordination, based mainly on Bray-Curtis similarities comparing these gnammas with those from the WA Wheatbelt, Eyre Peninsula and Central Victoria (Figure 8). Each geographic area contains closely related inselbergs/gnamma groups, with the gnammas of the Stanthorpe Plateau the most distinct. Different dominant species in each region cause these separations (see Timms 2014a, 2017); for the Stanthorpe Plateau these species are Diptera (*Paraborniella tonneri*, *Dasyhelea* sp., *Aedes* spp.) and the clam shrimp *P. urukhai*. Interestingly, the first two species are common to all four areas, but are dominant on the Stanthorpe Plateau, probably due to the lack of other species.

TABLE 3. Comparison of community complexity in four groups of pan gnammas across Australia

| Parameter | Wheatbelt WA* | Eyre Peninsula SA† | Central Victoria‡ | Stanthorpe Queensland mean (range) |
|---|---|---|---|---|
| Average pool depth (cm) | 17.6 | 17.3 | 9.1 | 5.6 (5–20) |
| Areal Species Richness | 220 | 55 | 50+ | 34+ |
| Inselberg Species Richness | ca. 60 | ca. 35 | ca. 35 | 15.6 (11–27) |
| Pool Cumulative Species Richness | 41–51 | 29–32 | 32–33 | 8.6 (3–27) |
| Pool Momentary Species Richness | 17.6 | 9.7 | 8.1 | 5.6 (2–18) |

* From Jocque et al., 2007; Pinder et al., 2000; Timms, 2012a, 2012b, 2014, 2017.
† From Timms 2014, 2017.
‡ From Timms, 2017.

FIGURE 8: Ordination of four groups of gnammas across Australia



*Shallow Gnammas and Short Hydroperiods*

One stark distinction of the gnammas on the Stanthorpe Plateau is their shallowness. The average depth of the 26 gnammas studied (5.6 cm), which included all the deepest gnammas that could be located, is less than a third of the average depth of those studied in the Wheatbelt (17.6 cm) and on the Eyre Peninsula (17.3 cm), and less than two-thirds of those in Central Victoria (9.1 cm).

Differences in gnamma depth between these regions are likely due to different modes of formation. In the west, for example, it is thought that pan gnammas are formed by rock dissolution along surface and near surface laminations split off by high summer temperatures (Twidale & Corbin, 1963; Twidale & Vidal-Romani, 2005). The depth of the lamination zone in Western Australia and South Australia can be as much as 30 cm, and rock dissolution may also be aided by cyclic salt (Timms & Rankin, 2015). Once a depression is formed, rock is stripped, lamina by lamina, resulting in a flat-floored pan gnamma commonly 10–30 cm deep with sloping or steep sides (Timms, 2012a,b, 2014a; Timms & Rankin, 2015).

On most of the Stanthorpe Plateau granite outcrops with gnammas, laminations are rare (though the surfaces are usually irregular), the gnamma shapes are irregular, and the edge profiles differ from those in Western Australia and South Australia. One factor may be temperature differences. Although the Stanthorpe Plateau lies further north, summer temperatures there are not as high (BOM, 2018), presumably associated with higher elevations (800–1200 m ASL, Table 1). Also, rain on the Stanthorpe Plateau has almost no cyclic salt (as indicated by very low conductivities in the pools, Table 1). Therefore, the main site of attack is probably at the air–water–rock interface, with dissolution occurring mostly at the pool margins over a narrow range. Rainfall at Stanthorpe is relatively high, averaging 767 mm per year and, though summer-dominated, occurs throughout the year. This means pools are often wet, so rock attack at the edges is persistent. Of course, past conditions would have been different, resulting in slower or quicker gnamma formation. This process causes mainly sideways spread of the gnamma, rather than deepening, and results in the C-shaped edge profile and irregular shape typical of most gnammas on the Stanthorpe Plateau. Sometimes, the pool overflow has been lowered, probably by erosion, and the dissolution process has recommenced at a lower level, resulting in a B-shaped edge profile, with only the lower part holding water. In contrast, the edge profile of gnammas in the west and south is evenly sloped (steep or low angled, or sometimes undercut at the laminations).

The shallowness of most Stanthorpe Plateau gnammas severely limits the duration of hydroperiods. This is exacerbated by the rainfall pattern, with more rain falling in summer – when evaporation rates are high – than in winter. In contrast to the Stanthorpe Plateau gnammas, the Wheatbelt and the Eyre Peninsula, in addition to having deeper gnammas, have a Mediterranean climate, with most rain falling in winter. As a major determinant of hydroperiod, gnamma depth is likely to strongly influence species diversity.

*Short Hydroperiods and Gnamma Fauna Diversity*

The likely importance of gnamma depth, as a surrogate for hydroperiod, in determining biotic diversity in pan gnammas is demonstrated by a strong correlation ($r = 0.9354$, $n = 26$) between depth and cumulative species richness for the 26 studied gnammas on the Stanthorpe Plateau (see also Figure 7). It is possible the high level of organic detritus present in one gnamma may have enhanced diversity, but our data are insufficient to prove this. During a year of monitoring in one of the deepest pools on the Stanthorpe Plateau (the 7.5 cm Dragonweyr 1 gnamma), only one of eight hydroperiods (those of sufficient duration for clam shrimp to hatch) lasted longer than six weeks (Figures 5 and 6). The consequence of this for the sustainability of local clam shrimp populations is discussed in the final section.

A similar relationship is evident for gnammas in central Victoria and on the Eyre Peninsula: those with shorter hydroperiods also have lower species richness (Timms, 2012a, 2014). It is also consistent with the conclusions of other studies – including Anusa et al. (2017) in Zimbabwe, and Brendonck et al. (2015) and Calabrese et al. (2016) in Western Australia – and similar results have been obtained in studies for which pool volume was used as the surrogate for hydroperiod, including Bayly (1997) for Western Australian gnammas and Timms (2017) for Victorian gnammas.

It has been suggested that the high species richness in the Wheatbelt gnammas is due to a favourable environment for speciation, including the isolation of granite outcrops, seasonally stressful environmental conditions and climatic fluctuations (Pinder et al., 2000). However, hydroperiod differences are also likely to influence diversity in Western Australian gnammas. The crustacean groups that are particularly diverse in the Wheatbelt (cladocerans, ostracods, copepods)

are less diverse in Western Australia's Goldfields gnammas, where hydroperiods are shorter than in the central Wheatbelt (Timms, 2012b; Brendonck et al., 2015).

The gnammas in central Victoria – which also manifest a correlation between shorter hydroperiods and lower diversity (Timms, 2017) – are thought to have been largely unaffected by past climatic fluctuations; indeed, speciation may have been suppressed in south-eastern Australia by the aridity of the ice ages (Williams et al., 1998). Hence, speciation scenarios were probably quite different in the south-east and the west, with the Eyre Peninsula between these two extremes, though its quota of endemic species suggests it was largely insulated from western climatic fluctuations by the vast, dry Nullarbor Plain.

Too little is known about the Stanthorpe Plateau gnammas and the genetics of their fauna to speculate about other factors influencing their diversity, such as dispersal constraints. About a third of the 35 gnamma taxa (crustaceans, planarians) rely on passive dispersal to colonise gnammas and maintain genetic connections. The others are active dispersers, with the adults able to fly (Jocqué et al., 2010). With waterbirds rarely frequenting the Stanthorpe Plateau gnammas (as indicated by direct observations and a motion-induced camera at one gnamma), it is likely that wind is the major dispersal agent (Graham & Wirth, 2008; Vanshoenwinkel et al., 2008, 2010a). This is effective over short distances within inselbergs, but of unknown efficiency for the longer distances between gnamma groups on the Stanthorpe Plateau, especially given that the intervening terrain is largely forested. Although wind-assisted dispersal between inselbergs must be rare, over sufficiently long periods it can occur often enough to maintain genetic connections (Vanschoenwinkel et al., 2011), meaning that local processes (such as hydroregimes) can be more important than regional processes for explaining large-scale diversity patterns (Brendonck et al., 2015).

Vanshoenwinkel et al. (2009) maintain that the hydroregimes of gnammas affect passive dispersers (crustaceans, planarians) more than active dispersers (insects). In this study the status of the active dispersers was unclear. Except for the dipterans, their presence is incidental except in the few deeper gnammas, notably at Billy Goat Hill. Most non-dipteran records are of one to two individuals rarely present in the shallow, markedly stochastic gnammas, and hardly count as part of their fauna (CSR is increased but MSR hardly at all). By contrast, in the deepest gnammas, actively dispersing bugs and beetles are persistently present and typical components of their metacommunity (contributing to both CSR and MSR).

*Adaptations for Short Hydroperiods*

The short hydroperiods of most Stanthorpe Plateau gnammas prevent or curtail breeding – explaining why juvenile beetles and bugs are rarely encountered – and limit inhabitants to species with short life cycles or life stages that don't rely on water, or to those with special adaptations such as drought-resistant eggs or larvae.

The chironomid *Paraborniella tonneri* and the ceratopogonid *Dasyhelea* sp., typically abundant in Stanthorpe Plateau gnammas, are preadapted by their cryptobiotic lifestyle (Jones, 1971), enabling larvae to survive in situ during dry periods and emerge quickly after inundation. It is not surprising that both are found in pan gnammas across Australia. Mosquito larvae are also preadapted to live in temporary waterbodies (Williams, 2006), so their ubiquity in pan gnammas is also expected, though populations seem to be greater in Stanthorpe Plateau gnammas than in those elsewhere (Pinder et al., 2000; Timms, 2012a,b, 2014a, 2017). This could be due to the fewer competitors for resources, given the low diversity of organic matter feeders (e.g. cladocerans, ostracods) in the Stanthorpe Plateau gnammas.

The crustacean inhabitants of gnammas are adapted to intermittent hydroperiods by producing desiccation-resistant eggs, only a fraction of which hatch during each hydroperiod. This is a bet-hedging strategy enabling species persistence when pools dry up before reproduction occurs (Brendonck et al., 2017) – as occurs frequently for clam shrimps in the shallow Stanthorpe Plateau gnammas. Even in the deeper gnammas (>6 cm), except in the 20 cm deep Billy Goat Hill gnamma, *P. urukhai* can fail to reproduce successfully during the summer storm season (Figure 8) or in drought years, e.g. in 2018 (BOM, 2018). Local extinction results if the egg bank is depleted by short hydroperiods occurring too frequently. Almost all pan gnamma groups in Australia have one species of clam shrimp, often endemic to that group (Timms, 2018). The presence of other crustaceans with desiccation-resistant eggs is variable between regional gnamma groups, with the Stanthorpe Plateau group by far the most depauperate. This could be largely influenced by the short hydroperiods occasioned by shallowness, but other factors as discussed above could be influential.

Little is known about the other inhabitants of the

Stanthorpe Plateau gnammas. Like the crustaceans, planarian species survive the dry periods by desiccation-resistant eggs (encased in a leathery cocoon) and rely on passive dispersal to colonise pools. Most gnammas across Australia have at least one planarian species. The only non-dipteran insect found regularly in the Stanthorpe Plateau gnammas is the small beetle *Sternopriscus multimaculatus*. Like the other, less common, beetles and hemipterans, it survives dry times by being elsewhere and flying in when water is present. The presence of the widespread snail *Isidorella hainesii* in the Billy Goat Hill pool was a surprise, given that aestivating snails could not be found in the benthic debris when the gnamma was dry. They probably disperse largely via birds and water flow. Nematodes are probably more common and widespread than indicated by pan gnamma studies so far, as sampling techniques are inadequate to catch them and taxonomic resolution has not been achieved.

As the only gnamma specialist on the Stanthorpe Plateau that can practicably be monitored, the clam shrimp *P. urukhai* offers the best opportunity to document the impacts of hydroperiod on gnamma inhabitants.

*Life Cycle of* Paralimnadia urukhai

The life cycle of *P. urukhai* is typical of that for limnadiid clam shrimps (Cáceres & Rogers, 2015). It is univoltine, hatching from eggs in the sediment soon after rainfall. Initially, it grows quickly, then much more slowly. Reproduction is dioecious, involves mate guarding, and occurs many times during sustained hydroperiods, usually at moulting. Death occurs when the pond dries, or earlier if resources are limiting.

Although clam shrimp eggs usually hatch together in response to suitable hydration, temperature and light cues (Fryer, 1996), multiple hatchings are occasionally possible, as occurred for *P. urukhai* in the Dragonweyr 1 gnamma in March 2018 (probably due to extra rainfall events that wetted more bottom sediment; see Figure 6a) and as has been recorded for *P. badia* in Western Australian gnammas (Benvenuto et al., 2009).

A comparison of the life cycle of *P. urukhai* (as documented in the Dragonweyr 1 gnamma) with that of *P. stanyleana*, which inhabits sandstone pools in the Sydney basin (Bishop, 1968), reveals many similarities but also a few differences. Both grow quickly after hatching: *P. stanyleana* reached 4 mm within 7–10 days, then grew slowly over the next few months to 6–7 mm (Bishop, 1968), while *P. urukhai* reached 3 mm within 10–14 days and then grew more slowly to a maximum of 6–7 mm (Figures 5b and 6b). *P. urukhai* can grow larger than this if the hydroperiod is longer – in the Billy Goat Hill gnamma, they reached about 9 mm.

Both *P. urukhai* and *P. stanyleana* grow more quickly in summer than in winter (Bishop, 1968; Figures 5b and 6b). For example, *P. urukhai* averaged 5 mm length after about 10 weeks in winter, but after only 3 weeks during summer. This is an effect of temperature seen in many clam shrimps, including *Eulimnadia brauriana* in Taiwan (Huang & Chou, 2017), likely to be due to faster growth of algal food sources during summer, a parameter not studied in Dragonweyr 1.

For both *P. urukhai* and *P. stanyleana*, numbers fall rapidly in the first few days after hatching, then plateau or decline slowly (Bishop, 1968; Figures 5b and 6b). For the Dragonweyr 1 gnamma, neither pH nor conductivity changes seemed responsible, but in at least one population crash, overnight oxygen depletion was suspected due to the suddenness of deaths. We suspect, but have no evidence, that algal food resources may be overwhelmed by the initial high shrimp numbers leading to starvation until the population falls to a sustainable level. The response of algal spores to wetting may be slower than hatching of shrimp eggs, especially if gnamma filling is accompanied by overcast days.

In many pools, *P. stanleyana* shrimp died of senescence after about four months (Bishop 1968a). There is little indication of this with *P. urukhai*; in the Billy Goat Hill gnamma, this species showed no signs of senescence even after seven months.

Most hydroperiods for *P. urukhai* populations on the Stanthorpe Plateau are short. Although the winter 2017 hydroperiod in the Dragonweyr 1 gnamma lasted almost 16 weeks (Figure 5a), the maximum duration of the six other hydroperiods during the year of intense monitoring ranged from 8 to 34 days (Figure 6a). For shallower gnammas nearby, even during winter, the maximum hydroperiods lasted no more than a few weeks. Only the winter hydroperiod in the Dragonweyr gnamma resulted in substantial reproduction. Three hydroperiods during the warmer months may have resulted in a small amount of reproduction (based on the occurrence of mate guarding), but the number of eggs laid would have been exceeded by the number of eggs hatched. Despite the reproductive failures during the warmer months, we estimated (very roughly) that

three times more eggs were produced than hatched over the whole year, suggesting the population in the Dragonweyr 1 pool is sustainable.

However, in a study on fairy shrimps in South Africa, it was estimated that an average 55% of eggs (range 10–80%) were lost between laying and hatching (Pinceel et al., 2010; Vanschoenwinkel et al., 2010; T. Pinceel, pers. comm.), and in *P. stanleyana* only 61% of eggs contained embryos (Bishp, 1968b). If similar losses apply to *P. urukhai*, based on the 2017–2018 hydroperiods, the Dragonweyr 1 population is only just sustainable.

Given these hydroperiod constraints, it is not surprising that most of the shallower gnammas on the Stanthorpe Plateau lack clam shrimps. Hulsmans et al. (2008) showed a similar relationship between pool depth and sustainability for the branchiopod shrimp *Branchiopodopsis wolfi* (Daday, 1910) in pools in Botswana.

Should the winter generation of *P. urukhai* be curtailed by lower rainfall, higher evaporation rates or a change in rainfall patterns leading to more frequent short hydroperiods, the species could be in peril in many gnammas. For instance, the 2018 winter was much drier than that of 2017, and eggs did not hatch in the one filling (due probably to it being too cold), so egg bank replenishment was zero. Climate change projections for the region – in particular, decreases in winter and spring rainfall and higher evaporation rates (Queensland Department of Environment and Resource Management, 2009) – imply that *P. urukhai* populations will experience greater stresses in future.

The ephemerality of pan gnammas is a challenge for aquatic invertebrates. As exemplified by *P. urukhai*, a species well adapted to intermittent hydroperiods, the gnammas of the Stanthorpe Plateau are more challenging than most due to their shallowness. This study illustrates the likely significant role of rock-pool depth, as a surrogate for hydroperiod, in determining biotic diversity in pan gnammas.

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## APPENDIX 1: GRANITE BELT GNAMMAS

### Species Lists and Abundances

| | Sites* | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **SP1** | **SP2** | **SP3** | **SP4** | **SP5** | **SP6** | **SP7** | **SP8** | **SP9** | **SP10** | **E1** | **E2** | **E3** | **E4** | **E5** | **T1** | **T2** | **T3** | **D1** | **D2** | **BR1** | **BR2** | **BR3** | **BR4** | **BR5** | **BGII** |
| unidentified large ciliate | | | | | | | | | | | | | | | | | | | | | | x | | x | | |
| unidentified planarian | | xx | | | x | | | | xx | x | x | | | | x | x | x | | x | x | x | x | x | x | x | |
| unidentified nematodes | | x | | x | | | | | | | | | | | | | x | x | x | | x | x | x | x | x | |
| *Paralimnadia urukhai* | | xx | | | x | x | xx | | xx | xx | x | x | | | x | x | x | x | xx | x | x | xxx | xx | x | x | xxx |
| *Neothrix armata* | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Anthalona* n. sp. | | | | | | | | | | | | | | | | | | | | | | x | x | | | x |
| *Armatalona imitatoria* | | x | | | | | x | | | | x | | | | | | | | | | x | x | x | x | x | x |
| *Armatalona macrocopa* | | | | | | | | | | | | | | | | | | | | | | x | | | | x |
| *Ilyodromus* n.sp. | | | | | | | x | | | | | | | | | x | | | | | x | x | x | x | | x |
| *Cypretta* n.sp. | | | | | | | | | | | | | | | | | | | | | | x | x | x | | |
| *Boeckella triarticulata* | | | | | | | | | | | | | | | | | | | x | | | | | | | x |
| *Cloeon* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Hemicordulia tau* | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | x |
| *Micronecta* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Agraptocorixa parvipunctata* | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Sigara* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Anisops gratis* | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Anisops thienemanni* | | | | | | | | | | | | | | | | x | x | | | | | x | | | | x |
| *Anisops stali* | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Anisops* sp. | | | | | | | | | | | | | x | | | | | | | | | | | | | x |
| *Enithares* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Berosus* spp. | | | | | | | | | | | x | | | | x | | | | x | x | | | | | | x |
| *Allodessus* larvae | | | | | | | | | | | | | | | | x | x | | x | | | x | | | | |
| *Antiporus gilberti* | | | | | | | | | | | | | | | | | | | x | x | | | | | | |
| *Eretes australis* | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Macrogyrus* larvae | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Rhantus suturalis* | | | | | | | | | | | x | x | x | x | x | | | x | x | x | | | | | | x |
| *Sternopriscus* larvae | | | | | | | x | | x | | | | | | | | | | | | | x | x | x | | x |
| *Sternopriscus multimaculatus* | | | | | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x |
| *Paraborniella tonnoiri* | xx | xxx | x | xx | xx | xxx | xxx | xx | xxx | xxx | x | xx | xx | xx | xx | xx | xx | xx | xxx | xx | x | x | x | xx | x | xx |
| *Chironomus tepperi* | | | | | | | | | | | | | | | | | | | | | | x | | | | x |
| *Dasyhelea* sp. | xx | xxx | xx | xx | xx | xxx | xx | x | xxx | xxx | xx | xx | x | x | x | xx | xx | xx | xxx | xx | xx | xx | x | x | x | x |
| *Aedes rubrithorax* and *A.* sp. | x | xx | x | x | x | x | x | x | xx | xx | x | x | x | x | x | xx | xx | x | x | | xxx | xx | xx | x | x | x |
| *Isidorella hainesii* (Tyron, 1866) | | | | | | | | | | | | | | | | | | | | | | | | | | xx |
| *Hyalinella* sp. | | | | | | | | | | | x | x | x | x | x | x | | | | x | | x | | | | x |
| DEPTH (cm) | 3 | 6 | 3 | 5 | 6 | 6 | 8 | 4 | 7 | 6 | 7 | 4 | 3 | 4 | 5 | 7 | 6 | 5 | 7 | 5 | 7 | 9 | 6 | 6 | 5 | 20 |
| VOLUME ($m^3$) | 0.014 | 0.055 | 0.119 | 0.047 | 0.032 | 0.141 | 0.192 | 0.636 | 0.168 | 0.013 | 0.264 | 0.496 | 0.212 | 0.418 | 0.028 | 0.495 | 0.272 | 0.094 | 0.568 | 0.319 | 0.079 | 0.407 | 1.108 | 0.218 | 0.088 | 4.412 |

* SP = Sow and Pigs Rock; E = Egernia; T = Tumbledown; D = Dragonweyr; BR = Bald Rock.

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# CREATING AND THEN ABOLISHING BODIES OF SCIENTIFIC KNOWLEDGE, EXPERTISE AND ANALYTICAL CAPABILITY: AN AUSTRALIAN POLITICAL MALAISE

MARLOW, D.[1]

Australian governments have a long and inglorious record of establishing valuable, valued and successful science-based initiatives that address issues of major continuing importance, only to later abolish them. The results are loss of focus, loss of group knowledge, loss of expertise, loss of analytical capability, wasted effort and resources, wasted expenditure – and most of all, wasted opportunity and wasted priceless time.

There are so many instances of this highly destructive political behaviour over so many years, committed by governments of both major political persuasions at both national and state level, that it should be recognised as an ingrained political behaviour and a basic endemic flaw in the Australian political system – a flaw that urgently needs correction, if Australia is to achieve a peaceful, sustainable future.

This paper presents a necessarily incomplete account of nine science-based bodies that met premature and unnecessary deaths at the hands of politicians – the Commission for the Future (CFF), the Resource Assessment Commission (RAC), Land & Water Australia (LWA), Queensland's Regional Open Space System (ROSS), the National Land and Water Resources Audit (NLWRA), the Sustainable Rivers Audit (SRA), the Native Fish Strategy (NFS), the National Water Commission (NWC) and the Climate Commission (CC). It describes some of their successes and some of the deleterious consequences of their abolition, the political reasons for their axing and the rationales used to justify the executions.

The paper calls for academic study of (and insider perspectives on) these and other valuable science-based initiatives killed off by Australian state and federal governments, so that the worth of these endeavours is recognised and remembered by the scientific community and by society at large. It concludes with a discussion of how this destructive political silencing of scientists might perhaps be reduced in frequency and significance.

Keywords: loss of scientific expertise, political interference in science, abolition of scientific, Land & Water Australia

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## DEFINITIONS

In this paper, 'government' is defined as 'the *political* entities of direction and control exercised over the actions of the members of a nation, state or local community', and the public sector is defined as 'the commissions, authorities, agencies, statutory corporations, strategies, audits, departments, systems, programs and units responsible for the management and administration of the affairs of a government'. Any political 'ignorance' refers only to any politician's lack of knowledge of science and the scientific method of problem-solving, not a lack of broader intellectual competence. In this paper, 'science' is the cluster of scientific disciplines appropriate to natural resource management (NRM), including strategic planning and the dynamics of complex systems. The science-based initiatives described in this paper are public sector initiatives.

## SCIENCE, POLITICS AND THE NEED TO REMEMBER

"Science, then is fundamental but only has full effect when it is public, and when those responsible to interpret what science tells us are prepared to speak truth to power" (Perry, in Science Media Exchange, 2019).

The scientific community has a societal responsibility to chronicle the life and death of public sector science-based platforms that spoke truth to power – and were possibly abolished *because* they spoke truth to power. In Santayana's memorable words, "Those who cannot remember the past are condemned to repeat it" (1905, p. 284).

### *The Political Sidelining and Silencing of Science*

The Australian political class has ill-served the nation and prejudiced the nation's future by its increasing

exclusion of scientists, scientific advice and even scientific evidence from governmental decision-making.

Governments are often confronted with 'inconvenient' truths in the advice tendered by scientists in public sector agencies. Some governments accept these truths and deal as best they can with the consequences of these truths. However, all too many governments have regarded some scientific truths (and sometimes even the scientific method of impartial rational discourse, itself) to be unacceptably at odds with the ideological mindset of the ruling political party or coalition of parties. This is particularly so, when scientific advice is seen as an obstacle to a particular economic project or influential development interest. All too many governments regard a truly independent scientific voice as an unacceptable impediment to 'business-as-usual' – that is, to the favouring of powerful business interests and to the centralisation of the governmental decision-making process within the political establishment. These governments then set out to silence the scientific messengers.

These governments (of both major political persuasions) employ a number of highly effective methods to 'nobble' the voices of scientific caution in public sector entities:

1. Impose an economic, planning or development philosophy that is largely antipathetic to impartial, long-term, science-based decision-making.
2. Appoint 'their man' to head the offending organisation, so that he or she can enforce compliance, silence the recalcitrant scientists, restructure the roles of offending scientists to roles 'more attuned to government priorities', or simply ignore their advice.
3. Downsize the offending organisation, outsource functions to compliant private bodies and consultants, and/or reduce budgets so that the scientific work can no longer be effectively carried out.
4. Abolish the offending organisation.

This paper deals with the ultimate weapon – abolition.

*A Roll-call of the Dead*

Australian governments have a long and inglorious record of establishing valuable, valued and successful science-based initiatives that address issues of major continuing importance, only to later abolish them. There are so many instances of this highly destructive political behaviour over so many years, committed by governments of both major political persuasions, that it should be recognised as ingrained political behaviour. This basic endemic flaw in the Australian political system urgently needs correction, if Australia is to achieve a peaceful, sustainable future. Too often, the political party that created the scientific initiative has also been the political party that abolished it – all it has taken is a change in leadership. Table 1 provides a far-from-exhaustive list of valuable, valued and successful science-based initiatives ignobly axed by governments.

*The Silent Deaths of Science-based Initiatives*

Media outlets rarely report on the worth or the accomplishments of science-based initiatives when those initiatives are contributing to the nation's good, or mourn them when those initiatives are shut down. There are many dispiriting reasons for this silence. The Murdoch media empire is openly small-government, anti-environment and anti-science; the moderate press has undergone savage cutbacks to journalist numbers with resulting loss of specialist journalistic expertise; the ratings-driven commercial television networks pursue trivialities and artificially generated controversies; the public is largely ignorant of (and uninterested in) complex and arcane scientific endeavours; the public is also uncaring if some 'self-serving scientists' and 'lazy, over-paid bureaucrats' get the sack.

Knowledge is a form of infrastructure, an input into other bodies' activities and, by its nature, is rarely on public display. Of all the entries in the Table 1 list, only the Climate Commission did not go quietly (because of the controversial political circumstances of its abolition and the very public stand taken by its chief commissioner).

This media silence feeds, deepens and perpetuates the ability of politicians to abolish science-based initiatives. It is responsible for a lack of public appreciation for the worth of science-based initiatives – and a lack of public awareness of the deaths (and the costs of those deaths) when those initiatives are abolished. Consequently, governments expect that they can abolish science-based initiatives without suffering any adverse electoral consequences. This knowledge breeds a political culture that regards the work of scientists as of little political and societal significance, and the advice of scientists as of little account in governmental decision-making.

*Speaking for the Dead: the Role of Scientists*

There are few insightful peer-reviewed papers on the achievements of science-based initiatives, or on the societal costs resulting from the deaths of those

initiatives. In the roll-call of the dead of Table 1, only the Resource Assessment Commission appears to have received detailed academic analysis of its work and of the politics of its establishment and abolition.

One reason for this academic silence is that most scientists in the relevant fields are public servants. Public servants are reluctant to be seen as self-promoting when the initiatives are operational, too busy to work up media programs and, in any case, banned from entering public policy debates. However, other scientists and academics do have the freedom to publish. Of those, insiders to or beneficiaries of these initiatives should be particularly encouraged to publish the histories of these initiatives. Each history would describe the highs and lows, the achievements, the costs to the nation resulting from the abolition – and the politics responsible for the abolition. It ought to be possible to write such histories in a dispassionate, analytical manner without defaming individuals. While these histories remain unwritten, this past will not be remembered and this nation will be condemned to the endless repetition of the same mistakes.

However, it is not only the scientists and politicians who need to remember this past and learn the correct lessons from it – the wider Australian society needs to do so, as well.

## GOVERNMENTS, SCIENTISTS, THE PUBLIC SECTOR AND THE PUBLIC INTEREST

"The primary function of governments is to protect the public interest" (Edwards, 1998).

The pursuit of science needs to serve the long-term interests of society. To effectively do so, scientists and scientific institutions need to continuously communicate the critical societal worth of science-based initiatives to a public that is largely unaware of that worth. Indeed, scientists and scientific institutions have an inherent *obligation* to communicate the societal worth of the work done by those initiatives to the society that financially supports those initiatives. Two notable quotations emphasise the point.

"Vast sums of government dollars go to fund academic and government research. Even if the government chooses to ignore the results of that research, scientists have a responsibility—what Jane Lubchenco, former president of the American Association for the Advancement of Science, called a social contract—to communicate the lessons of their research to the public. A majority of scientists, including me, have also been educated at public institutions. The public whose dollars pay for educational institutions and government granting agencies have a right to expect some public good from action based on scientific findings. They [the public] cannot benefit if scientists do not speak up and use their knowledge to inform and influence the policy process" (Karr, 2006).

"Communicating with the public is an important duty for an academic. If the task of researchers is, as one analyst observed, 'to seek the truth and make it known', making your findings known is essential" (Lowe, 2018).

TABLE 1. Gravestones – a sample of the birth and death of science-based initiatives, 1985–2015

| **Science-based initiative** | **Creator** | **Destroyer** | **Born** | **Died** |
|---|---|---|---|---|
| Commission for the Future (CFF) | Hawke Labor government | Howard LNP government | 1985 | 1998 |
| Resource Assessment Commission (RAC) | Hawke Labor government | Keating Labor government | 1989 | 1993 |
| Land & Water Australia (LWA) | Hawke Labor government | Rudd Labor government | 1990 | 2009 |
| Regional Open Space System (ROSS) | Goss Queensland Labor government | Newman Queensland LNP government | 1994 | 2012 |
| National Land and Water Resources Audit (NLWRA) | Howard LNP government | Rudd Labor government | 1997 | 2008 |
| Sustainable Rivers Audit (SRA) | MDB Ministerial Council* | Baird NSW LNP government† | 2000 | 2012 |
| Native Fish Strategy (NFS) | MDB Ministerial Council* | Baird NSW LNP government† | 2003 | 2012 |
| National Water Commission (NWC) | Howard LNP government | Abbott LNP government | 2004 | 2014 |
| Climate Commission (CC) | Gillard Labor government | Abbott LNP government | 2011 | 2013 |

* The Murray-Darling Basin (MDB) Ministerial Council comprises Ministers from the Queensland, New South Wales, ACT, Victorian, South Australian and Australian governments.

† "State governments in September quietly canned funding for the popular Native Fish Strategy, following a NSW government cut in its contribution to the Murray-Darling Basin Authority – the body overseeing the river – by $20 million" (Arup, 2012b).

*Note*: LNP is an acronym for the Liberal Party–National Party coalition.

Scientists working in the public sector have a fundamental responsibility to serve the public interest to the best of their abilities. In the Australian Public Service (APS), there is an implicit recognition of this fundamental responsibility. Section 10 (APS Values) of the *Public Service Act 1999* states that one of the values of the APS is 'Committed to service', where the APS "works collaboratively to achieve the best results for the Australian community and the Government" (Federal Register of Legislation, n.d.). In Queensland, the recognition is explicit. Section 7 (Promoting the public good) of the *Public Sector Ethics Act 1994* requires public service agencies, public sector entities and public officials to "accept and value their duty to be responsive to both the requirements of government and to the public interest" (Queensland Parliament, 2014).

However, there seem to be no formal guidelines on what this responsibility entails. Edwards (2011) postulated six axioms as a foundation for a standard of public interest. Two axioms were biophysical ("There is only one planet available to support human life" and "Economic growth in a finite world is unsustainable"). Two were sociological ("The common good has both individual and social dimensions" and "Humans exhibit both a private persona, a motivation towards self-fulfilment; and a public persona, a motivation to participate in public affairs and to advance the common good"). Two were public policy ("Governments exist to advance society's well-being" and "International UN treaties are normative [i.e., determine norms or standards]"). He asserted that when even one of these axioms was conceded, the public interest would have to embrace policies that gave effect to it. The author uncovered no evidence that any official body in Australia has adopted this schema or anything comparable.

## THE POLITICS OF CONFLICTING DEVELOPMENT PHILOSOPHIES

### *Neoliberalism versus Ecologically Sustainable Development*

"In spite of modifications under hybrid approaches, neoliberalism still tests achievement of sustainability goals, due to privileging industry and shifting risk and costs to future generations, through inadequate regulation, neglect of public consultation, lack of transparency, and weak impact assessment" (Baldwin et al., 2019).

Australian politics has been dogged for decades by the conflict between two competing and antagonistic philosophies that can underpin the development and management of natural resources:

1. Neoliberalism
   [which can be defined as the "belief in sustained economic growth mediated by free markets as the most efficient means to achieve human progress. In a neoliberal planning system, the emphasis is placed on economic activity, growth and employment, and other values are regarded as secondary considerations" (McFarland, 2011)].
2. Ecologically sustainable development (ESD)
   [which can be defined as "using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased" (Australian Government, 1992)].

Neoliberalism regards environmental considerations as a barrier to and a limitation upon economic development. ESD regards environmental considerations as paramount to achieving a sustainable, high quality-of-life.

### *Shifting Political Attitudes*

"Land-use planning systems in Australia are currently dominated by a neoliberal approach in which the focus is primarily on administrative efficiency and economic growth" (McFarland, 2011).

The supposedly left-wing Australian Labor Party (ALP) has long had a right-wing focus on supporting industries in the resources sector. This has been partly due to the influence of the forestry and mining unions – now part of the Construction, Forestry, Maritime, Mining and Energy Union (CFMMEU). Under former Treasurer then Prime Minister, Paul Keating (1983–1996), the ALP became nakedly neoliberal. "Keating's agenda revolved more around his interest in matters to do with economic restructuring … In the face of a deliberate move to reassert Labor's interest in more overtly materialistic policy matters, there occurred an inevitable decline in the degree of access environmental interests had to the institutionalised policy-making process" (Economou, 1996). "While Bob Hawke had taken a strong personal interest in the environment, Keating, rejecting most things championed by Hawke, treated environmental issues with a dismissiveness bordering on contempt" (Hamilton, 2001, p. 34).

The always-pro-business Liberal Party was not always anti-environment. "The last decade of the

Howard government has obliterated the memory of progressive Liberal Party policies on the environment and climate change during the late 1980s. [In 1990], under shadow environment minister Chris Puplick, the [Liberal Party–National Party] Coalition had progressive environmental policies on a number of issues … 'We were at one with [Labor] on CFC [chlorofluorocarbon] control and CFC emissions. We were ahead of them on the Antarctic … We were ahead of them on whaling issues – that was a legacy of Fraser's long involvement'. Importantly, he claims that the Coalition was ahead of the Labor Party on global warming issues by the 1990 election" (Staples, 2009).

In present federal and state politics, both Coalition and Labor governments pursue planning, development control and ecosystem management systems that regard economic development as the dominant consideration. Science deals mainly with the complexities of the natural world and the universe, not artificial, necessarily simplistic, human-centric economic constructs. A large body of science thus seeks to understand the complex interplay of complex natural systems and the essential role they play in making human life possible. This science seeks to chronicle the damage to those systems by human activities, better manage those systems and improve the health of those systems. This scientific work is essential to ESD, but the precautionary policies that should flow from it are an impediment to unrestrained economic development. Neoliberal views dominate in the present political, corporate and media climate (Barnes, Humphrys & Pusey, 2018; Quiggin, 2018; Manne, 2013), despite the electoral unpopularity of the term. As a consequence, cautionary scientific messages are often 'inconvenient' and their scientific messengers unwelcome.

Gathering and/or publicising knowledge about environmental matters – landscape, waters, climate – risks attracting political enmity. Every science-based initiative listed in Table 1 dealt with these matters. The only organisation in the list with multiple areas of interest was the CFF – see Table 2. However, the CFF attracted hostility from both Coalition and Labor Party politicians, because it chose the 'greenhouse effect' (now known as the innocuous-sounding 'climate change') as its primary focus (McKinlay, n.d.; Lowe, 1989, pp. 5–7). The birth and death of these initiatives can thus often be traced to the ebbs and flows of the political struggles between the acolytes of neoliberalism and ESD – respectively the right-wing economic 'dries' and the left-wing environmental and social 'wets'.

## THE MECHANICS OF THE POLITICAL ABOLITION OF SCIENCE-BASED INITIATIVES

### *Reasons for Abolition: the Reality Behind the Spin*

There are four major reasons for the political abolition of science-based initiatives in the public sector – see Table 3:

1. Ideology
   In the list of nine science-based initiatives killed off by governments, two raised public awareness of major 'environment versus development' issues (CFF, CC), three were explicitly involved in the ideological battleground of NRM (RAC, ROSS, NWC), two were tasked with supplying the resource datasets for NRM (NLWRA, SRA), and the other two supported NRM (LWA, NFS) – see Table 2. Pro-economic-development, anti-environment politicians and political parties have invented their own doublespeak for removing environmental restrictions and checks on the activities on the property, construction and mining industries – 'cutting green tape'. This includes cutting the science-based initiatives responsible for the environmental checks.
2. Ignorance of the value of science and/or disrespect for science and scientists
   Johnston (2016) observed that "in federal parliament, only 20 politicians have training in a discipline related to science, technology, engineering, maths or medicine (STEMM). That's just 7 per cent of MPs (11 out of 150) and 12 per cent of senators (eight out of 76). That's far lower than the proportion of Australians graduating with degrees in STEMM which, although declining, is still a reasonably healthy 33 per cent". She mounts a compelling case for improving government decision-making by electing scientists to leadership roles within Australian political establishments. However, it is not essential that politicians hold science degrees for them to make good policy decisions on science-related issues. What is essential is that government ministers have trusted advisers to accurately and clearly explain the implications of the science that is relevant to the issues on which ministerial judgments need to be made. It is also essential that all politicians acquire at least a basic understanding of the role of science in society and the power of the scientific method – and not be dogmatically anti-science in their mindsets. However, neither of these needs is recognised in the Australian political system

and no political mechanisms exist to satisfy these needs. With very few politicians trained in STEMM disciplines and no mechanisms in place to encourage politicians to gain even an educated layman's understanding of the value of science, many – perhaps most – politicians remain ignorant of the true value of science-based initiatives [Reason 2a]. Consequently, they may also be unsympathetic or even antipathetic to the very concept of science [Reason 2b]. The problem is probably exacerbated, because politicians would understandably view scientists in the public sector as little more than technicians. In the Queensland public service (and doubtlessly in other public services), scientists rarely hold decision-making authority, because they need to transfer from a professional pay scale to an administrative one if they are to become managers, and managers are the feeders for promotion to executive rank. Ignorance of the value and rigour of science and antipathy towards science and scientists contribute to a political disdain for impartial scientific advice – which is then ignored, dismissed, not sought, or silenced. However, because these are usually internal mindsets, the extent of their role is not capable of evidential proof.

TABLE 2. Principal function, aim or goal to be achieved by the abolished science-based initiatives

| Body | Principal function, aim or goal to be achieved by the initiative |
|---|---|
| CFF | Initiate a continuous public information process to 'demystify' science and raise public awareness of the social and economic impacts of technological change, addressing in particular concerns about the effect of such change on employment (National Archives of Australia, n.d.b). |
| RAC | Resolve competing claims for the use of resources (Federal Register of Legislation, 2004). |
| LWA | Act as a research investor (to achieve the *sustainable* management and use of Australia's natural resources) and as a leading research broker, organising collaborative research and development programs (Land & Water Australia, 2009a). |
| ROSS | *Regional Frame* – provide a frame to urban development, defining the limits of the metropolis.<br>*Recreation* – provide opportunities for both passive and active recreation.<br>*Conservation* – protect the natural environment.<br>*Landscape* – contribute to the scenic quality of the landscape and the liveability of South East Queensland.<br>*Economic Potential* – provide opportunity for sustainable commercial activity (Edwards, 2019a). |
| NLWRA | Provide nationwide assessments of Australia's land, vegetation and water resources now and in the future: collate and assess data on natural resource issues to provide information in forms suitable for decision makers, recommend monitoring and assessment systems for Australia's natural resources, design and implement an Australian Atlas to display data collated during the Audit to form a basis upon which a range of natural resource related datasets could be displayed within a distributed network Australia-wide (NLWRA Advisory Council, 1999). |
| SRA | Provide a continuing, systematic assessment of the health of river ecosystems across the Murray-Darling Basin (MDB), to provide ecological data to support major and rapidly evolving investments in river management (Davies et al., 2010). |
| NFS | Rehabilitate native fish communities in the Murray-Darling Basin back to 60 per cent of their estimated pre-European settlement levels, after 50 years of implementation (Murray-Darling Basin Ministerial Council, 2003). |
| NWC | Provide independent assurance of the Council of Australian Governments (COAG) national water reform agenda, promote the objectives agreed by all governments in Australia under the 2004 Intergovernmental Agreement on a National Water Initiative (NWI), assess the implementation of water reforms by all jurisdictions, provide strategic guidance and information, and provide independent advice and reports. The NWC was also required to audit the effectiveness of the implementation of the Murray-Darling Basin Plan and associated water resource plans and assess performance against reform commitments in water management partnership agreements under the Murray-Darling Basin Agreement 2008 (National Water Commission, 2015). |
| CC | Provide all Australians with an independent and reliable source of information about the science of climate change, the international action being taken to reduce greenhouse gas emissions, and the economics of a carbon price (National Library of Australia, 2012a). |

3. Political perceptions of expendability
   Decades of neoliberal privatisation of front-line scientific service provision to the public – such as to rural landholders – have reduced science-based work in the public service to mainly back-room knowledge-gathering operations. Associate professor Ruth Nettle from the Faculty of Science at the University of Melbourne estimated that "Nationally there has been about a 38–40 percent drop in government funded extension positions since 2009–2013". Dr Nettle said it was the third wave of cuts since the 1980s (Australian Broadcasting Corporation, 2015). With much-reduced staffing levels, and now with little contact with the public they serve, the remaining scientists (with their knowledge and expertise) linger, largely unnoticed and largely unappreciated by the public and the media. This near-invisibility means that governments know that they can casually abolish these science-based operations and not suffer any significant electoral backlash, even when the work is critical for good governmental decision-making. Consequently, whenever a government budget 'razor gang' is seeking budget cuts that will not hurt the chances of the government's re-election, science-based initiatives are regarded as easily 'expendable'. No government in Australia's history appears to have suffered an electoral backlash as a result of any such abolition. However, because no politician would ever confess to holding such a belief, the extent of its role is not capable of evidential proof.
4. Hoarding or rearranging power within the political establishment
   Science is a diffuse method of gaining knowledge. Within the scientific and technological community, world views often differ – a mining engineer will have a mindset very different from that of an ecologist. However, the processes of science are essential to gaining an ever-greater human and societal understanding of complex socio-environmental-economic realities. Science that is allied to public consultation and participation – a common thread in the casualty list of Table 2 – is an innately democratising process, antipathetic to a political culture of secretive machinations. Public sector agencies that are truly independent of governments can be bothersome to governments. Support for the establishment of the agency may be enthusiastic, but the support base narrow. Once established, the government may become uncomfortable with the lack of political control over the agency, and when the chief proponent moves or is moved to other responsibilities, abolition becomes a convenient option. The rise and fall of the CFF exemplifies this phenomenon – see Table 3. Independent statutory authorities are particularly bothersome to governments, because they often prove to be unamenable to political control and can't be easily ignored. A frustrated government may then seek to permanently silence the troublesome voice.

These reasons interact to create a political culture that makes it easy to denigrate, sideline and silence the voice of scientists in governmental decision-making.

*Rationales for Abolition: Justifying the Unjustifiable*

Governments that abolish these science-based initiatives usually feel the need to furnish a public explanation, however specious or spurious, to justify their actions. Government-appointed heads of now-compromised public service departments are sometimes required to furnish an explanation, when they axe their own scientific units. One or more of the following rationales are used by governments to justify the abolition of science-based initiatives – see Table 3.

Rationale 0: No justification is offered.

Rationale 0 has scenarios instead of sub-rationales (there can be no sub-rationale for a non-explanation). However, the scenarios can be instructive – Scenario 0a (progressive strangulation) is always a sign of political malice. Scenario 0b (sudden dramatic funding cuts) usually indicates political malice, but sometimes may be the result of mere government incompetence.

Scenario a: The initiative is progressively so starved of funds, so denuded of staff, so restricted in its fiat, so marginalised by the government that it can no longer function properly. The government then quietly shuts it down, with its clientele so reduced that few people care that a valuable knowledge, planning or management resource has just been destroyed (the CFF, the ROSS – see Table 3).

Scenario b: The initiative is operating normally, when the government unexpectedly so steeply slashes or even ends funding that the initiative can no longer function, and ceases operation. This can arise when the government wants to rid itself of an obstructive science-based

initiative and hopes that if it says nothing at all, nobody will notice (the RAC, the SRA, the NFS – see Table 3). However, it can also come about merely because the government fails to recognise the value of the initiative and sees its demise as nothing of any note (the NLWRA – see Table 3).

Rationale 1: The initiative is no longer necessary, because its work is now done, the purpose has been fulfilled.

This justification is especially favoured, because the decision is made to appear a cause for public approbation, rather than a cause for public condemnation.

Rationale 2: The work has been transferred to other instrumentalities.

Sub-rationale a [This will increase efficiency of service delivery] is particularly popular with governments, because it portrays them as nobly trying to gain more value from the taxpayer funds spent on a public service that the public 'knows' is inefficient. It is not explained how the transfer of functions would improve efficiency.

Sub-rationale b [The initiative is redundant] is the 'nothing to see here' defence. It portrays the abolition as mere harmless bureaucratic reshuffling or manoeuvring, with no effect on future outcomes. Governments invariably mention only the functions that have been transferred, thereby insinuating – but not stating – that all functions have been transferred, when in reality major programs have been quietly discontinued. LWA exemplifies this consequence – see Table 4. This scattering of the functions to the four winds effectively destroys the focus of the initiative and reduces the effectiveness of the now potentially uncoordinated effort, while the government escapes censure for the destruction. The NWC exemplifies this consequence – see Table 4.

Rationale 3: It is a budget-saving measure, and the savings made are better spent elsewhere.

This rationale portrays the government as sound economic managers, diligently gaining the greatest benefit from taxpayer dollars. However, this rationale is often transparently false, because the announced budget savings are either trivial (see the CC in Table 3) or illusory (see LWA in Table 4).

Rationale 4: Belittle the worth of the initiative.

Openly belittling the initiative being abolished is rare, because it looks – and is – nasty. However, it does happen. Inserting words like 'nowadays' is important, because it justifies not having abolished the body earlier. Additionally, if the same ruling party created the initiative in the first place, the implication of 'nowadays' is that it was a fine and noble initiative, when it was first established.

Interestingly, even when it is made obvious to everybody that an initiative has been abolished for ideological reasons, the axing is never justified on those grounds. An example of this is the Abbott Coalition government's abolition of the Climate Commission. The Abbott Coalition Government (2013–2015) was elected on an "Axe the [Carbon] Tax" platform of reversing action to combat climate change. It was sworn into office on 18 September 2013. Later that day, as its first act in office, the government abolished the Climate Commission (Talberg, Hui & Loynes, 2016). Yet, the axing was publicly justified solely on streamlining processes, avoiding service duplication and saving money, even though the savings quoted were manifestly miniscule – see Table 3.

Political niceties thus seem to need to be observed when announcing the executions, but this makes it much harder to gain a precise understanding of this destructive political phenomenon.

### *Epitaphs: Lives Well Lived and the Consequences of Abolition*

All of the science-based initiatives listed in Table 1 made valuable contributions to society. Their premature deaths at the hands of governments have had lasting, adverse consequences for the societies they once served – see Table 4.

There are always significant (sometimes major and long-lasting) costs to a state or the nation, when its governing parties abolish important, successful initiatives. The public sector suffers loss of group knowledge, loss of expertise and loss of analytical capability. Often, the associated strategic data-capture operations are terminated and ultimately abolition becomes a shameful waste of public funds and irreplaceable scientific group memory. Key datasets steadily degrade in quality as they are no longer updated. Painstakingly captured data may be dumped. Access to archived data may become increasingly difficult, as systems are no longer actively maintained. The mere existence of the archived data may be largely forgotten. There are other significant and undervalued societal costs to be paid. For example, the abrupt political severing of cooperative ventures with clients and stakeholders leads to a loss of multiplier-effect opportunities and

breeds considerable ill-will – see LWA, the NLWRA and the NWC in Table 4 for illustrations of the costs to societal harmony.

A public sector shorn of such capabilities can no longer contribute as it should to government decision-making. The end-result will inevitably be misdirected governmental priorities and flawed governmental decisions. When scientific advice – almost always cautious, given scientists' natural reliance on demonstrable evidence – is discarded, there is the risk of widespread and often permanent environmental damage and inadequate management of increasingly stressed ecosystems. Society in general will suffer as problems unnecessarily persist, because opportunities have been lost and resources and funding wasted. The problems themselves become less amenable to solution, because of the loss of focus in addressing them – and the loss of skilled personnel to address them.

However, the cruellest cost is wasted time – priceless, irrecoverable time – where genuine progress to a better future for the state or the nation is erased as if it had never existed.

TABLE 3. Probable reasons for (and rationales used to justify) the abolition of the science-based initiatives

| Body | Reasons and rationales for the abolition of the initiative |
|---|---|
| CFF | Reasons: 1, 2a, 2b, 4.<br><br>"It was not supported by Jones' [Labor] government colleagues or by Coalition politicians. I still remember the hostility [Reasons 1 and 2b] and ignorance [Reason 2a] of some elected members when I appeared before the Senate Estimates Committee to defend the CFF's meagre budget. It was not surprising that the CFF's public funding was discontinued, when Jones was no longer the responsible minister" (Lowe, 2016, p. 87).<br><br>"At the time [the 1980s], the problem wasn't denial. The climate change conspiracy theorists were yet to emerge. Nor was it a question of party-line hostilities—they, too, would emerge much later. Indeed, more concern was shown for the issue [the greenhouse effect] on the conservative side. The problem was just that it was early days for anxiety. What the Commission for the Future was shouting about belonged to … the future [Reason 2a]" (McKinlay, n.d.).<br><br>"The CFF was designed to be at arm's length from government and free to encourage discussion without political or bureaucratic constraint [Reason 4]" (National Archives of Australia, n.d.a).<br><br>Rationale 0a ["It limped along for a few years with limited resources from the private sector, before finally being wound up" (Lowe, 2016, p. 87)]. |
| RAC | Reasons: 1, 2a, 4.<br><br>"A number of matters associated with the Kakadu Inquiry contributed significantly to a decline in support for the RAC in some parts of the Commonwealth government, including disappointment that the RAC did not recommend a specific course of action, and, in some circles, that it did not recommend that mining go ahead … concern was expressed in some quarters that it gave detailed attention to cultural issues affecting indigenous people [Reason 1]" (Stewart & McColl, 1994).<br><br>"Politicians and bureaucrats were unhappy about the transparency of the political process. Given the preference for hiding behind the cloak of expert advice, the government surprised few when it decided in the 1993–1994 Budget round to abolish the RAC. The Commission's crime was to use a rational and visible process, thus exposing the nature of the decision to the public gaze [Reason 4]" (Lowe, cited in Stewart & McColl, 1994).<br><br>"Hawke's departure from the leadership brought this period of extraordinary federal institutional interest in the environment to an end, and the RAC suffered as a result … Without Richardson, the government failed to realise the utility of the RAC as a place to shunt seemingly intractable disputes between noisy interest groups. Without Hawke, the RAC's place in the general scheme of reforming policy-making along consensual lines was no longer recognised [Reasons 1 and 2a]" (Economou, 1996).<br><br>Rationale 0b ["the government gave no public explanation of its decision not to provide further references to the RAC" (Stewart and McColl, 1994) and "… as part of the cost-cutting exercise by the Keating government, the commission's fate was sealed by a small announcement in the budget paper that it would cease to exist in the new financial year. Amidst the controversy surrounding the budget's problems in the Senate, the death of the RAC was hardly noticed" (Economou 1996)]. |

| Body | Reasons and rationales for the abolition of the initiative |
|---|---|
| LWA | Reason: 2a.<br>This appears to be a result of the Rudd Labor government's continual shifts in priorities, in response to external pressures. "Rudd's government was elected in 2007 with an ambitious program for change, [but] these ambitions were thwarted by a range of factors, not the least … managing his massive agenda which constantly elevated issues to 'first order priority'" (Aulich & Evans, 2010).<br>In a Senate estimates hearing in May 2009 (during the Global Financial Crisis of 2007–2009) on being asked the question "Why are we axing such a central research organisation?", the Superannuation and Corporate Law minister replied that natural resource management was now a mainstream issue for government and the community, but "We're doing as much as we can afford to … and in times of economic contraction you have to make some hard decisions" (Anon., 2009).<br>Alexandra and Campbell (2013) viewed the Rudd Labor government's axing of LWA as a 'strategic blunder', not an ideological act.<br>Rationales 2b and 3 ["The 2009 federal budget papers implied that LWA had become redundant, because 'a number of tertiary, public and private sector bodies have been established in the natural resource management research and development field' since its formation in 1990 [Rationale 2b]" and "The 2009 federal budget announced the disbandment of LWA, with associated savings of $45.9 million over four years [Rationale 3]" (Robins & Kanowski, 2011)]. |
| ROSS | Reasons: 1, 2a, 4.<br>In 1995, probably 2a and 4 (tensions between planners and scientists within separate departments of the public service). In 2012, probably 1.<br>Rationale 0a [No public scholarly explanation of the reasons for the demise of the ROSS is known. The initiative was announced by the Premier on 28–29 May 1994 as confined to public land (19% of SEQ) and private land purchased or covenanted by agreement (another 6%). It came into operation on 1 July 1994 but ran into difficulties within its first 12 months after maps were published showing some 50% of SEQ, including large tracts of land covered by landscape-type zones as included within the ROSS. The pivotal issue was land tenure rather than science. Hostility from rural landholders caused the secretariat to be shuffled from one department to another and its budget for land acquisition and park development to be appropriated by others. Reconstituted as the Regional Landscape Strategy, it continued until abolished in 2012 along with the regional planning unit, a victim of the Newman government's general hostility towards environmental protection and 'green tape'. The Minister for Planning at the time was on record as asserting that the purpose of planning was to facilitate economic development (Edwards, 2019a)]. |
| NLWRA | Reason: 2a.<br>Additionally, Creighton (2018) saw bureaucratic jealousies as a contributing factor: "As for the demise of Audit 1 – well the agencies that were supposed to build policy off our evidence felt we had too much control."<br>Rationale 0b [The end of the NLWRA came as a line in the 2009 budget. However, even though the tasks assigned to the NLWRA were ongoing, its funding never was]. |
| SRA | Reason: 2a.<br>Rationales 0b and 3 [The NSW government appears not to have provided any specific explanation as to why it suddenly and savagely reduced its contribution to jointly funded river operations and natural resource management programs administered by the MDBA. However, successive NSW Coalition governments make no secret of their continuing hostility to what they see as outside interference in their management of 'their' river system. The Murray-Darling Basin Authority (2013) stated: "After the NSW state government cut its funding, the Basin governments made the decision to cut the Native Fish Strategy and the Sustainable Rivers Audit, and delayed maintenance programs." However, the other governments made no public criticism of the actions of the NSW government and made no attempt to take up the slack].<br>Rationales 2b and 4 [Later, in 2016, the MDBA used other justifications: "Since the end of the SRA, the MDBA has established a monitoring program to gather information about the environmental impact of the Basin Plan at the Basin scale [Rationale 2b]" and "Basin state and territory governments decided to cease funding the SRA program as it did not align with the monitoring of ecological health required under the Basin Plan – The SRA monitored ecological health compared to a pre-European benchmark. It was also not linked to specific water management actions like the Basin Plan [Rationale 4]" (Murray-Darling Basin Royal Commission, 2019)]. |

| Body | Reasons and rationales for the abolition of the initiative |
|---|---|
| NFS | Reason: 2a. Rationale: 0b and 3 [see the SRA rationale for details]. |
| NWC | Reason: 4 (an independent statutory authority being too independent is the most probable reason, because of the multiple sometimes conflicting rationales and the political resort to denigration [Rationale 4]).<br>Rationales 1, 2b, 4 ["Liberal Senator Simon Birmingham said the purpose of the commission had been fulfilled [Rationale 1] and its roles would be taken over [sic] the Productivity Commission [Rationale 2b], saving the budget $20.9 million over four years [Rationale 3]. Much of the savings will be absorbed by an aid agency to help other nations improve their water management. 'Nowadays it's nothing more than a government-funded commentary organisation' [Rationale 4], Senator Birmingham told Fairfax Media. The Productivity Commission will provide 'more robust, more independent, more fearless criticism than the NWC has shown the likelihood to do to date' [more of Rationale 4]" (Hannam, 2014)].<br>Rationales 2a and 3: Liberal Senator Mitchell Fifield (2014) said, "Given both the substantial progress already made in water reform [Rationale 2a] and the current fiscal environment [Rationale 3], there is no longer adequate justification for a stand-alone agency to monitor Australia's progress on water reform. In line with reform priorities to improve efficiencies across the Australian Government and to improve the budgetary outlook, the NWC will cease its functions following the release of its assessment of national water reform in October this year." |
| CC | Reasons: 1, 4.<br>The Abbott LNP government (2013–2015) abolished the Climate Commission as part of its campaign to reverse government action on mitigating anthropogenic climate change. Talberg, Hui and Loynes (2016) list the abolition of the Climate Commission, followed by repeated failed attempts to abolish the Clean Energy Finance Corporation, the Climate Change Authority and the Australian Renewable Energy Authority, the abolition of the Emissions Trading Scheme and the reduction of the 2020 Renewable Energy Target (RET) [Reason 1].<br>The Climate Commission was an independent expert body – its deliberations, reports and public engagements were not subject to Ministerial direction [Reason 4] (National Library of Australia, 2012b).<br>Rationales 2a and 3 ["Mr Hunt [the Environment Minister] confirmed that he had dissolved the commission. 'As part of the Coalition's plans to streamline government processes and avoid duplication of services, the commission's function to provide independent advice and analysis on climate change will be continued by the Department of the Environment [Rationale 2a]', he said …'This decision will save the budget $580,000 in 2013–14 and an annual funding of up to $1.6 million in future years [Rationale 3]'." (Arup, 2013)]. |

*Note*: Reason 3 (the perceived political-electoral expendability of science-based public sector initiatives) may well be a factor in all of the abolitions of Table 1, but was never cited as a factor.

TABLE 4. Epitaphs – achievements in life and the consequences of premature deaths

| Body | Achievements and the consequences of premature death |
|---|---|
| CFF | The CFF did what it was tasked to do – raise public awareness of issues affecting the future (see Table 2).<br>In 1987, the CFF and the CSIRO conducted a major scientific conference (*Greenhouse '87*) that addressed how specific scenarios of climatic change in Australia would impact on Australian farming, water supplies, ecosystems, coastal development, public health, etc. In 1988, the CFF conducted *Greenhouse '88* – a media event to focus on responses to the greenhouse effect. "From the day I landed in Sydney, it was nonstop media, government, or public events. It looked like a political campaign. A dozen interviews in one day, plus flights from Melbourne to Canberra (to brief the national Parliament), to Sydney (to do a press conference), and back to Melbourne (to talk to water planners) were all crammed into 24 hours! This was typical of the pace for five days before the national broadcast. After that, I had to fly to Perth to participate in still more meetings, press conferences and public discussions … The Greenhouse '88 week was to be composed of dozens of 10-minute interviews by radio and television stations and reporters from localities all over Australia" (Schneider, 1989, p. 240).<br>"The awareness of the greenhouse issue is probably greater amongst the general public in Australia than in any other country in the world. This is partly because the last two years [1987–1988] have seen meetings devoted to the topic of the greenhouse effect" (Henderson-Sellers & Blong, 1989, p. 155). Unfortunately, "the public" didn't include the politicians. "We published documents, convened conferences, imported experts, held meetings in town halls across Australia. There was a dramatic response from scientists and public alike but a negligible reaction from our politicians" (McKinlay, n.d.). |

| Body | Achievements and the consequences of premature death |
|---|---|
| CFF (*cont.*) | "That was the aim of the CFF: to remind Australians that there is a wide range of possible futures and stimulate discussion of what country we would like to be in the twenty-first century" (Lowe, 2016, p. 88). In the present Australia of fake news, the 24-hour news cycle and the 30-second political sound bite, there is now no political and societal discussion of what this country should aspire to become and no vision for its future. |
| RAC | "… the RAC stands as an important development in the history of environmental policy creation at the national level. With its emphasis on comprehensive processes involving fulsome investigation of land-use debates, 'independent' analysis of data and information, and multilateral interest-group and public participation, the processes of land-use policy formulation in the RAC period stand in contrast to an earlier period in which decisions were made on an ad hoc basis usually as the result of a reactive campaign conducted by environmentalists aggrieved by the failure of old processes to take environmental considerations into account" (Economou, 1992).<br><br>"The decision not to continue the RAC on an on-going basis means that there is no longer a body concerned directly with the development of methods and expertise for analysing major resource issues. While there was considerable movement of staff in and out of the RAC secretariat, particularly in exchanges between government agencies, the accumulated expertise of the RAC in dealing with resource issues constituted a valuable public asset which has now been dissipated. In addition, the lack of opportunities for personnel from government agencies and elsewhere to participate in the work of an independent and objective body such as the RAC in examining major resource issues represents a considerable loss" (Stewart & McColl, 1994).<br><br>"In one of those perennial ironies of administrative politics, the very government that could have benefited from having a statutory authority like the RAC towards whom it could, in the immediate term, push developers, environmentalists and others in a bid to come up with a consensual outcome on what should be done about logging in Australia's native forests, was the same government that killed off just such a body" (Economou, 1996).<br><br>"The demise of the RAC represented a demise in the idea of 'better policy-making' as based on careful, proactive, inclusive decision-making" (Economou, 1996). |
| LWA | This completely publicly funded statutory rural research and development corporation listed 15 significant achievements, including the AUSRIVAS system for measuring river health, developing the model for collaboration of states and other agencies to address the major landscape challenge of dryland salinity, leading multi-partner programs (to manage climate variability and Australia's northern rivers, improve irrigation systems, and develop Australia's national Climate Change Research Strategy for Primary Industries), working closely with the cotton industry to eliminate pesticide contamination of waterways and working with the wool, meat and grains industries to develop more-sustainable mixed farming systems (Land & Water Australia, 2009b).<br><br>A conservative independent study in 2006 by consultants Agtrans found that LWA had delivered \$4.80 in direct economic benefits for each government dollar invested, equating to an internal rate of return (IRR) exceeding 24% (Robins & Kanowski, 2011).<br><br>The abolition of LWA in 2009 caused the cancellation of a large number of contracts with university-based and other researchers across Australia and the closing-down of many partly completed research projects (Land & Water Australia, 2009c).<br><br>The 2009 budget terminated almost all research within the Rural Research and Development Corporation system that was not matched by industry levy contributions.<br><br>LWA was the peak body supporting research designed to inform and strengthen the regional NRM model through programs such as the Social and Institutional Research Program (SIRP) and Knowledge for Regional NRM. These programs did not have equivalents (or replacements) elsewhere in the Australian R&D arena (Robins & Kanowski, 2011). |
| ROSS | No public scholarly evaluation for the early days is known. Unpublished departmental documents indicate that in the first 12 months (to May 1995) the program achieved the following:<br><br>*Planning*: regional open space attributes mapped and given to local governments; six specific locality reports; consultants' reports obtained on implementation through statutory planning and tenure, landscape of Tamborine Mountain, Bicentennial National Trail and wader roosting sites. |

| Body | Achievements and the consequences of premature death |
|---|---|
| ROSS (*cont.*) | *Land acquisition*: 100 properties evaluated for purchase, 7 approved, 4 purchased, $4m fully committed.<br>*Development and maintenance*: park development projects funded at six reserves, mainly via local governments.<br>*Information*: a five-year, $7m program to supply base mapping and other land information for South East Queensland (SEQ) for all purposes was launched. This was suspended in 1996 when the incoming Borbidge Coalition government reviewed all procurement contracts (Edwards, 2019a).<br>This was just the first year. From 2004–2012, the achievements included:<br>• Queensland Greenspace Strategy<br>• SEQ Greenspace Network Plan<br>• SEQ State of Region Report<br>• Strategic Cropping Land Strategy<br>• SEQ Active Trails Strategy<br>• Brisbane Valley Rail Trail Plan and 96 km of trail open<br>• Maroochy River Trail Plan and works completed<br>• Boonah to Ipswich Trail Plan and 49 km of trail open<br>• Kingaroy to Theebine Trail (Business Plan & Feasibility Study) and key rail assets secured<br>• Queensland Outdoor Recreation Strategic Framework and demand studies<br>• SEQ Scenic Amenity methodology, Planning Guidelines & mapping<br>• SEQ Rural Futures Strategy and Rural Precinct Planning Guidelines<br>• Sustainable Poultry Strategy<br>• Water Sensitive Urban Design Planning Guideline<br>• North East Gold Coast land use and infrastructure strategy<br>• Landscape heritage discussion papers<br>• Rural and Greenspace Policy Forum and working groups<br>• Regional Landscape Forums (5)<br>• SEQ Regional Plan: policy development/review, notably Regional Landscape Planning Framework.<br>(Landscape Planning Team, 2012). |
| NLWRA | "I reconvened the original Audit team, including Commonwealth officers, to see how we could build on the first report for a second review, Audit II. We were keen to further quantify assessments where possible, add other components such as soil biota, and to start a process to more empirically assess trend, but there was no Commonwealth support for a comprehensive follow up. This burnt considerable jurisdictional goodwill across the States and Territories. Similarly, Col Creighton's push for a separate national resource monitoring and assessment body to be permanently established was never acted upon. The National Land and Water Resources Audit program, and then Land & Water Australia, a successful body providing natural resource management advice to rural Australia, were closed down by the Department of Agriculture, Fisheries and Forests. Subsequently, the Australian National Reserve System Program was closed down. The waste in setting up and then closing these successful Commonwealth programs was staggering" (Sattler, 2014).<br>"The NLWRA Terrestrial Biodiversity Assessment (TBA) was a very successful exercise in describing the condition and trend of a number of biodiversity elements across species and ecosystems for each bioregion, in identifying threatening processes, and biodiversity conservation opportunities and priorities for management. Fourteen case studies were also completed across the range of 'Landscape Health' scenarios to provide detailed insight into the specific mix of management responses required.<br>"This experience informed the Humane Society International (HSI) submission for a new approach in regional planning. Despite significant goodwill by all States and Territories at the time to further expand on the Audit's work, (it is estimated that the States and Territories contributed an additional $2m on top of the $1m allocated by the Federal government for the TBA), the Federal government of the day did not show leadership in this regard or accept HSI's submissions for a new cost effective approach to regional planning upon which to further roll out the Natural Heritage Trust program and its subsequent incarnations. Today little legacy exists of what was one of Australia's most expensive environment initiatives at that time" (Sattler, 2018). |
| SRA | The Commonwealth Government's 2016 State of the Environment Report stated: "The Sustainable Rivers Audit is the most comprehensive Basin-wide river health assessment available [in 2016]", but lamented "however, the most recent report covers 2008–10, so is not relevant to condition assessment after 2011" (Argent, 2017, p. 46). |

| Body | Achievements and the consequences of premature death |
|---|---|
| SRA (*cont.*) | "The main reason for a lack of proper monitoring of the environmental condition of the Basin is a lack of adequate government funding. The discontinuation of the Sustainable Rivers Audit was undesirable and inappropriate" (Walker, 2019, p. 65).<br><br>Witnesses at hearings of the Murray-Darling Basin Royal Commission "lamented the discontinuation of one of the Basin's most successful condition monitoring programs, the Sustainable Rivers Audit (SRA) … Dr Celine Steinfeld of the Wentworth Group of Concerned Scientists (Wentworth Group) submitted that, 'without the ability to track the condition of the Basin it is not possible to understand the ecological changes at a valley and Basin scale'. In Associate Professor Jamie Pittock's view, no program of commensurate independence and scientific rigour has replaced the SRA, and its absence represents a 'major failing'. Similarly, Mr Peter Cosier stated: 'Managing the health of the Murray-Darling Basin rivers without the Sustainable Rivers Audit would be like trying to manage the Australian economy without the national accounts. It's just not possible'. In a similar vein, Dr Anne Jensen observed that the SRA's discontinuation has prevented a thorough assessment of whether the Basin Plan requirement that there be no further decline in respect of prescribed environmental targets is being met" (Walker, 2019, p. 568). |
| NFS | The NFS was large-scale (the 1 million $km^2$ of the basin), focused on rehabilitation, not just managing the status quo, took a threat-abatement approach, considered both native fish and alien species, included all native fishes (not just angling species), was developed as a long-term approach given the scale of the problem, undertook significant public engagement and incorporated an independent review of progress (Koehn, Lintermans & Copeland, 2014).<br><br>Many (often multifaceted) projects were completed over the 10 years of the NFS, including 5 projects on 'Rehabilitating Fish Habitat', 3 on 'Protecting Fish Habitat', 14 on 'Managing Riverine Structures', 7 on 'Controlling Alien Species', 10 on 'Protecting Threatened Native Fish Species' and 3 on 'Managing Fish Translocation and Stocking' (Anon., 2014).<br><br>Koehn, Copeland & Stamation (2014) concluded: "While goals of the NFS remain, cessation of funding for the NFS programme after just 10 years appears short-sighted, particularly considering the plight of the fish and the NFS's achievements, and this has again left MDB fish populations in a vulnerable state. The lessons learnt from the NFS have, however, only reinforced the importance of the need for coordinated, basin-wide long-term solutions to fish recovery." |
| NWC | In a submission to the Inquiry into the National Water Commission (Abolition) Bill 2014, the chair of the NWC asserted: "The NWC has been unique in Australian water governance in its capacity to deliver a national interest perspective (as distinct from individual state, industry or Commonwealth perspectives), to provide independent, expert and credible advice, and to collaborate with partners in government, industry and academia to develop new ways to better manage water resources … Despite its small size, the NWC's collaborative and consultative partnership approach to its roles and functions, underpinned by its structure as an expert and independent body with a dedicated remit, ensured that it built up a strong basis of expertise … the expertise of the office dispersed rapidly following the announcement earlier this year of the Government's intention to abolish the agency. All subject matter specialists within the Commission (excluding corporate functions) have already left, or will be leaving shortly… a concern is that the splitting of the NWC's various roles [on its abolition] will inevitably lose the synergistic advantages of integration … Strengths of the NWC have been that it reports to all Australian governments and to COAG, its Commissioners were nominated by all states and territories as well as the Commonwealth for their specific expertise, and it provided a skills-based national perspective not driven by shorter term interests" (Parliament of Australia, 2014).<br><br>The National Irrigators' Council fully supported the government's abolition of the NWC. The National Farmers Federation (NFF) labelled the abolition as 'disappointing'. The South Australian government worried that the abolition risked "a loss of leadership knowledge and expertise as well as less effective support for, and scrutiny of water reform efforts". The Australian Conservation Foundation (ACF) labelled the abolition as "a short-sighted and backward step", that "would likely result in another wave of conflicts over water due to the absence of what all sides regard as a well-respected expert independent body". The Water Services Association of Australia (WSAA) opposed the abolition on the grounds that it "removes national water leadership, fearless advice and independent custodianship of the NWI [National Water Initiative]" (Parliament of Australia, 2014). |

| Body | Achievements and the consequences of premature death |
|---|---|
| CC | In its two-year life, the commission produced 27 public reports on topics that included the effects of climate change in Australia, global action being taken to reduce greenhouse gas emissions and the potential of renewable energy (Arup, 2013). It also held dozens of public meetings around the country to explain climate science, and no other body existed to serve that role (Hannam, 2013).<br><br>The chief climate commissioner at the time, Professor Tim Flannery, defended the Commission's role: "We've stayed out of the politics and stuck to the facts … As a result, we've developed a reputation as a reliable apolitical source of facts on all aspects of climate change … *I believe that Australians have a right to know – a right to authoritative, independent and accurate information on climate change …* As global action on climate change deepens, propaganda aimed at misinforming the public about climate change, and so blunting any action, increases" (Arup, 2013).<br><br>Professor Flannery said that he was not aware of any organisation that can do the same job – not even the CSIRO or universities: "The Bureau of Meteorology puts out advice and information on weather events, but doesn't cover the economics or international action happening around climate change … There are various other groups that may or may not be able to do some of it, but having an independent strong authority that's committed to just telling the facts as they are – we're the group that was doing that … You need a well-informed public in order to make the right sort of decisions" (Griffiths, 2013). |

## REFORMING THE SYSTEM

### *The Need for an Informed and Socially-committed Public*

"Politicians and policy-makers are unlikely to take the greenhouse effect seriously until their constituents do" (Henderson-Sellers and Blong, 1989, p. 155).

"Levels of [public] trust in government and politicians in Australia are at their lowest levels since times series data has been available" (Stoker, Evans and Halupka, 2018, p. 9).

A well-informed public, committed to addressing major social issues, can force politicians to reform their ways by threatening their political survival at election time. That public does not currently exist. However, this is now the time, when public trust in the political system is at an all-time low and likely to plummet further, to begin to forge that well-informed and socially committed public – a public that will recognise poor political performance and behaviour and demand better of their politicians.

### *The Involvement of Scientists in Society and in Societal Reform*

Scientists who are (or should be) involved in land-use strategic planning, natural resource management, natural asset research and societal awareness-raising shouldn't be supine victims of political machinations. They have a responsibility to work to serve the long-term interests of the society that educated them and allowed them to be scientists – which includes the long-term health of the biosphere that supports that society.

The scientific community also has an important role to play in the creation of a well-informed, socially committed public and a better future for the nation. It needs to create a compelling, scientifically rigorous argument and body of evidence to present to the public – and vigorously, continuously prosecute that argument in the public arena. However, the scientific community is highly diversified and is largely unorganised. Currently, it is not highly influential in major issues confronting the nation and is largely separated from the general community it serves. This state of affairs needs to change.

### *The Path of Reform*

The path of reform has two components pursuing separate but related goals:

1. Maximise the societal benefits of science (the goal directly relevant to this paper).
    a. Create an authoritative body of academic work – a scientific history – on the valuable science-based public sector initiatives that have been debilitated or destroyed by the actions of governments.
    b. Greatly increase the quality and extent of interaction between the scientific community (in academia, in the public sector, in the private sector) and the public.
    c. Greatly increase public and media respect for the knowledge, the expertise and the societal contributions of science and scientists.
    d. Return science and scientists to positions of credibility, respect and influence in governmental decision-making.

2. Create a well-informed and socially committed society that will place a high value on societal fairness, the overall public good and a healthy, biologically diverse natural environment – and so elect governments that will mirror the world view of that society.

*The Path of Reform: Maximising the Societal Benefits of Science*

This component of the path of reform can be envisaged as follows:

1. Create the body of evidence for national reform and for reform in each state.
   [Create a peer-reviewed, multi-paper history of the creation and later political debilitation or abolition of valued and valuable state and national science-based initiatives, the political imposition of philosophies antipathetic to impartial multi-disciplinary scientific deliberation and the political exclusion of scientific voices from policy deliberations. Where possible, these papers would be written by (or largely based on the experiences of) those who were there at the time.]
2. Create the 'Case for Reform' in each state and the nation.
   [Create a suite of peer-reviewed papers that categorise and integrate the papers of Step 1 to illustrate both the long history of this destructive political behaviour and the cumulative damage that it has done to each state and the nation. The Case for Reform needs to vividly convey both the critical importance and the urgency of the need for reform. To this end, each component of the Case for Reform would address a major relevant area or issue of concern. Such issues include the following: political attacks on renewable energy and the science of climate change; the political mismanagement of major specific ecosystems such as the Murray-Darling Basin; the political dismantling of scientific efforts to create the knowledge bases needed for good natural resource management; the effective political exclusion of public sector scientists from political forums, such as politically arranged business dinners. The Case for Reform would then define the commonality of causes between the individual components and propose solutions.]
3. Create scientific voices on the demonstrable value of science (particularly the science of understanding and managing natural assets) and the scientific method.
   [Professional scientific organisations and academic institutions, nationally or within each state (or individuals within these organisations and institutions) need to progressively cooperate to espouse the value of science and scientific advice to the politicians, media and public. For example, The Royal Society of Queensland should seek the cooperation of its sister state organisations, the Royal Societies of Australia, the Queensland Academy of Arts and Sciences, the Australian Academy of Science and any other relevant umbrella scientific bodies in this endeavour (Marlow, 2014).]
4. Progressively increase the number of science-based, policy-oriented symposia, forums and conferences that embrace and value the participation and involvement of community-based interests, to both build support for science-based policy-making in the community and directly benefit communities by the direct dissemination of valuable scientific advice and concepts.
5. Progressively increase two-way mutually beneficial interactions between scientists and the public in fields as diverse as regional policy-making, land-use determinations, land management practices, surface and ground water monitoring, ecosystem management and the empowerment of local communities in the rehabilitation of mine sites.
6. Promote the Case for Reform (specifically for a respected scientific voice in governmental decision-making) in each state and the nation (in an apolitical way) with the political class.
7. Promote the Case for Reform in each state and the nation (in an apolitical way) with the general public, by employing a wide range of media outlets (writing articles, supplying information, and so on).

This work will also further progress in the second component of the 'Path of Reform'.

*Immediate Priorities, Multiple Fronts*

The political abolition of valuable science-based initiatives is but one aspect of a wider malaise – the destructive misuse of Australia's scientific capabilities and the consequent prejudicing of Australia's future. There are multiple fronts that require immediate attention by

concerned scientists and academics, as the following list illustrates.

1. Organise, coordinate, create alliances, influence, seek reform.
   The Path of Reform proposed in this paper is both noble and necessary, but it is a lengthy process – and this nation needs immediate reform in this area. There are valuable lessons to be learned, even from this preliminary and limited analysis. These lessons need to be communicated to the scientists (particularly public sector scientists working in policy fields), the politicians and society in general (particularly political and societal reformers).

   If the scientists and society don't speak, the politicians can't listen. Some scientific professional organisations (particularly those in the natural sciences and strategic planning) need to take on this issue as a cause. In particular, the various state Royal Societies and their new collective body, the Royal Societies of Australia (RSA) should urgently pursue this issue. There is probably no issue more fundamental to any local Royal Society than the political sidelining and silencing of scientific voices. To its credit, The Royal Society of Queensland (publisher of this journal) has taken a public stand (Edwards, 2019b). The state Societies could exhort their members who were insiders to the abolition of valuable national science-based initiatives to write the histories of the fallen. As proclaimed upholders of scientific traditions, the RSA and the state Societies, along with the Australian Academy of Science, are in a better position than nearly any other body in Australia to understand the need to return science and scientists to their former respected positions in society and in the workings of government.
2. Gather the evidence on the politically slain. Create an authoritative, detailed scientific history (preferably written by witnesses to the events) of the valuable science-based initiatives that have been destroyed by the actions of governments. If this is not done, their contributions to the nation will not be remembered, or their histories will be written by their enemies. If this is not done, governments will persist in this destructive behaviour. If this is done, these initiatives will again serve their country, by serving as guideposts towards a better future.
3. Gather the evidence on the politically wounded. Create an authoritative, detailed scientific history (preferably written by witnesses to the events) of political interference in and distortion of public sector science. Specific examples may include the political interference in and tainting of Australia's iconic Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the political creation of development-focused super-departments, such as the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) in Queensland. Some analyses/histories would be more broad-scale – such as the increasing political exclusion of scientists and scientific advice from governmental decision-making, and the politicisation of once largely independent public services.
4. Gather the evidence on the academically slain. Create an authoritative, detailed scientific history (preferably written by witnesses to the events) of the valuable science-based initiatives that have been destroyed by the actions of academic bodies. Academic gravestones may include Rangelands Australia and the funding/de-funding of various valuable Centres of Excellence and Cooperative Research Centres. This parallel need became apparent during the work on this paper, but is outside the scope of this paper.

## IN MEMORIAM: HONOURING THE DEAD

We (meaning both the scientific community and society itself) particularly need to remember the dead, to chronicle their lives and deaths, to appreciate and honour their deeds, to mourn their passing, to give them respected places in Australian scientific history, to retain their knowledge, to learn from their experiences and to give their deaths value by no longer supinely and mutely allowing cavalier political executions of initiatives that have amply demonstrated their worth to society.

We owe them that.

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## AUTHOR PROFILE

The author began his career as a milling metallurgist with Mount Isa Mines at Mount Isa, before returning to the University of Queensland to complete his M.Sc. He later worked as Engineering Computer Manager for the South East Queensland Electricity Board, before moving to the Queensland Public Service, holding the position of Principal Research Adviser at his retirement. He has lately involved himself in investigating the benefits to be derived from the involvement of communities and professional organisations in the increasingly important issue of minesite rehabilitation, and in forging productive links between the scientific community and the society it serves (particularly regarding the issues of climate destabilisation and long-term socio-environmental sustainability).

# PROCESSES AND INSTITUTIONS FOR SCIENTIFIC INDEPENDENCE: REFLECTIONS ON LAND & WATER AUSTRALIA

ALEXANDRA, J.[1]

Independent and impartial scientific research provides critical contributions to many contemporary policy debates, including those about climate adaptation and natural resources. Therefore, institutional arrangements that enable and protect scientific independence are central to resolving environmental problems in advanced liberal democracies. This paper provides an overview of the research and development (R&D) funding organisation Land & Water Australia (LWA) that, due to its statutory independence, was effective and influential in promoting sustainable natural resource management. Established by legislation that provided structural independence, LWA was insulated from direct interference, enabling it to operate at arm's length from executive government. The paper profiles LWA contributions to changing policies and practices, and explores the features that enabled LWA to coordinate, organise and fund R&D, until its abolition in 2009. LWA provided a useful precedent of a statutory authority, chartered with a clear legislated purpose and legal mechanisms for ensuring independence. The paper highlights institutional arrangements that protect scientific independence, arguing that LWA provided an important model of public R&D investment directed to sustainability transformations.

Keywords: R&D policy, sustainability, natural resource management, land and water conservation, innovation, scientific independence

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## INTRODUCTION

Recent controversies involving water policies and questions of scientific independence have included those surrounding the South Australian Royal Commission into the Murray-Darling Basin (Walker, 2019), the groundwater plan for the Adani Carmichael mine (Currell & Werner, 2019), and the ongoing debates about the Great Barrier Reef and the massive fish kills in the Darling River (Australian Academy of Science, 2019). These debates highlight the need for institutional processes of ensuring scientific independence that are sufficiently insulated from political interference (Walker, 2019). However, achieving this ideal can be particularly challenging because the majority of Australian science is publicly funded, and funding decisions made by governments affect projects, programs and entire agencies. Therefore, institutional arrangements and organisational models of 'arm's length' funding arrangements that can minimise direct and indirect interference by Ministers and bureaucrats deserve serious attention.

This paper explores one example of such an organisation, that of Land & Water Australia (LWA) – a national statutory authority that funded R&D on natural resources management (NRM) between 1989 and 2009. Established as a statutory corporation – the Land and Water Resources Research and Development Corporation (LWRRDC) under the *Primary Industries and Energy Research and Development Act 1989* (PIERD) – its legislated mandate was to organise and fund R&D on the sustainable management and conservation of land, water and vegetation resources (Campbell, 2006).

This paper examines the case of LWA and the way it operated, for the purpose of discerning its key features and how these could be replicated in future arrangements. These include legislated arrangements for structural independence that minimised interference in its research funding decisions.

Despite its record of significant achievement, LWA was abolished in 2009 – ostensibly as a savings measure. Other reasons offered for this decision include increasingly strained relationships with the Minister and the Department after the election of the Rudd government,

and that LWA's relevance to the Agriculture Department was significantly diminished after the move of water policy responsibilities to the Environmental portfolio.

This decision to abolish LWA was widely criticised, including by political parties, the Australian Conservation Foundation (ACF) and the National Farmers' Federation (NFF) (APH, 2009). Yet a decade on, Australia lacks any similar agency, despite the Productivity Commission's (2011) recommending that "if the Government is serious about having its broader research priorities appropriately addressed within the RDC arrangements, it should create and fund a new RDC — Rural Research Australia — to sponsor non-industry research directed at promoting the productive and sustainable use of resources". In its draft report, the Productivity Commission recommended a $50 million annual allocation to this new entity, for public-good R&D (Campbell, 2010).

LWA's role in the nation's life deserves further analysis. As a research broker, it successfully initiated numerous collaborative R&D programs, facilitating purposeful co-investment with industry and governments. Its programs are too numerous to document comprehensively, so this paper takes a synoptic rather than comprehensive view of LWA's contributions, drawing on specific programs for illustrative purposes. Comprehensive documentation of LWA's diverse R&D programs can be found in Campbell (2006) and Campbell & Schofield (2007).

Many of LWA's R&D programs were relevant to Queensland (and northern Australia more generally), including work on water, rangelands, vegetation and savanna management. Its remit did not extend to marine and coastal waters, but R&D on catchments and riverine systems improved understanding of nutrient and sediment runoff processes affecting estuaries and near-coastal waters, including the Great Barrier Reef.

I was involved with LWA over its 20-year life, initially as a representative of the ACF (under the PIERD Act, LWA was required to formally consult with the ACF and NFF on its strategic plans), as a Board member (1996 and 2002), and as the Vegetation and Biodiversity R&D Program Coordinator (2002 and 2006).

This paper draws on that experience, and subsequent reflections on how R&D is organised and funded, to provide insights about the institutional settings that enable or constrain effective, policy-relevant R&D. My subsequent experience as a senior executive at the Murray-Darling Basin Authority (2008–2013) emphasised that well-structured arrangements for generating impartial scientific research are critically important to sound policy development and therefore to the functioning of advanced liberal democracies dealing with complex and compounding environmental problems, including climate adaptation (Ison et al., 2018; Walker, 2019; Alexandra, 2019).

The paper concludes with some ideas about institutional arrangements for revitalising public-good R&D. I argue that the experience of LWA provides important insights into the kinds of R&D arrangements needed to tackle the 21st century's systemic problems. These require purposefully designed, boundary-spanning organisations that can accelerate urgent sustainability transformations (Cash, 2001; Cash et al., 2003). Given this, Australia should create more entities like LWA, in the States and Commonwealth, that are empowered to generate transformative innovations across multiple domains, including agriculture, energy, water and urban planning. These entities need to be established using institutional designs that incorporate the best features of what has been learnt, in terms of directing R&D funding towards generating and adopting effective, policy-relevant innovations.

## ORIGINS AND MANDATE – ASSISTING RESOURCE POLICIES IN TRANSITION

LWA can be credited with contributing to NRM knowledge, driving institutional, policy and practical reform. However, its existence and legacy are framed by the wider operating context.

Since LWA's inception, profound changes occurred in Australia's policy settings for land, water and natural resources. The nation's cultural, institutional and economic relationships with natural resources have evolved. Across the continent, changing relationships with country[a] are manifesting in the policy and physical landscapes. Through numerous plans and policies, NRM goals have been redefined, incorporating objectives such as conservation of biodiversity and of the capacity to deliver ecosystem goods and services (Alexandra & Riddington, 2006).

LWA contributed to and reinforced this redefinition, recognising that Australia's rich and diverse landscapes help to shape our spirits, our values and cultural icons, and therefore our national character. LWA promoted the idea that "rural landscapes are

[a] 'Country' is a holistic term, encompassing land, water, plants and animals, and is often used to describe Aboriginal Australians' relationship to place, territory or region – as in 'Welcome to Country' ceremonies which are used to open conferences and meetings.

inherently diverse, and incorporate production, lifestyle and amenity values. They are socially constructed, reflecting the way natural resources are managed, perceived and understood ... While a factory, quarry or mine is an adequate analogy for systems that produce commodities: cathedrals, theatres, museums, universities or great art galleries are appropriate analogies for the multi-faceted relationships we have with nature" (Alexandra & Riddington, 2006).

These profound changes can be traced back to the late 1980s when the nation's institutions, identity and sense of place in the world were changing and when ambitious programs, like planting a billion trees to restore landscapes and inspire hope, were promoted (Eckersley, 1989; Campbell et al., 2018). Agriculture was declining in economic significance (Keating & Harle, 2004), but caring for country was elevated to a national ideal, including through Landcare initiatives (Marriot et al., 1999). The continent was no longer seen as a cornucopia of natural resources available for crude exploitation, but as an inherently valuable, bio-diverse continent in need of care (Alexandra & Riddington, 2006; Campbell et al., 2018).

In the 1980s, local land conservation groups, landcare groups and environmental restoration initiatives emerged independently in Victoria, Queensland and Western Australia (Campbell, 1994; Marriott et al., 1999). The ACF and NFF formed an alliance, campaigning for an end to land degradation and a decade of commitment to landcare (Toyne, 1992). Prime Minister Bob Hawke launched the Decade of Landcare at the confluence of the Murray and Darling Rivers in 1989 (Commonwealth, 1990), confirming that sustainable resources management was recognised as a national priority. That year, the Commonwealth also established LWRRDC, later rebadged as LWA (Campbell, 2006).

LWA's origins were in this 'landcare dreamtime' – the optimistic days of the late 1980s – when sustainable landuse was high on the nation's policy agenda (Campbell et al., 2018). The legislative mandate for LWA was to change the way natural resources were managed (Campbell, 2006) despite persistent and potent forces driving resource exploitation (Industry Commission, 1998). The idealistic goal of solving the "wicked problems" (APSC, 2007) of land degradation was enshrined in legislation. In effect, Australia had established a 'sustainability' research corporation whose mission became "generating knowledge, informing debate and inspiring innovation and action in sustainable natural resource management" (LWA, 2001).

This legislative mandate – with its clarity of purpose, ambition and inherent idealism – established a purposeful entity. The mandate was coupled with statutory independence and a relatively small, but discretionary R&D budget, strategically invested by successive Boards (Campbell, 2006). Using its R&D funds, LWA convened extraordinary networks – farmers, officials, researchers and conservationists – that together formed and activated Australia's NRM knowledge system, pursuing the ideal that conservation and production could be integrated (Campbell, 2006).

LWA explicitly recognised that the technical, cultural and social dimensions of NRM are intimately and inherently linked (LWA, 2001). LWA's land, water and vegetation R&D programs catalysed changing ideals about Australia's landscapes, celebrating them as places of diverse lifestyles and livelihoods (Campbell et al., 2018). Throughout the 1990s, local landcare and regional groups emerged as key actors in NRM (Curtis et al., 2014). A new ethos that many people called landcare[b] – was enthusing communities, infusing into policies, and diffusing through countless networks (Campbell et al., 2018). LWA supported these groups' efforts in tackling their land and water conservation priorities. Its R&D programs brought together diverse disciplinary perspectives of policy professionals, researchers and practitioners. Through these diverse partnerships, LWA created networks that recognised that NRM knowledge and practice are co-produced (Bouleau, 2014; Bremer & Meisch, 2017), and that partnerships offer the best prospects for achieving enduring change (Campbell, 1994; Alston & Whittenbury, 2011; Abel et al., 2016).

LWA recognised and reinforced an emerging culture of landscape restoration during a time when the nation's relationship with the continent was changing. Australians were becoming more respectful and appreciative, celebrating their landscapes' intricate patterns, rich biological diversity, and profound cultural history (Griffiths & Russell, 2018).

## A LEGACY OF WATER REFORMS – DAMPENING THE NATION'S WET DREAMS

In the 1990s, Australian water policy settings were under pressure to change. The Prime Minister's Science and Engineering Council warned that the continuation of past policies "will severely and adversely

[b] Landcare is used as a generic term, covering all land conservation efforts – not just those programs labelled as 'Landcare'.

affect every aspect of contemporary life" (PMSEC, 1996).

Australian governments agreed to national water reforms in 1994. These aimed to increase the productivity and efficiency of water use and ensure the health of aquatic systems, committing to environmental flows in all rivers, based on the best available science (COAG, 1994). These commitments have been repeated in all major water policies in the 25 years since 1994, including the Commonwealth Water Act; however, implementation has been challenging (Walker, 2019; Grafton, 2019). Despite recognising the central role of science in guiding the restoration of riverine ecosystems, there have been continuing contestations about how to apply science to this policy challenge. These contestations highlight the critical role of impartial and independent research in policy development and implementation (Alexandra, 2018; Walker, 2019).

Sustained R&D on river health and environmental flows can be traced to LWA-funded and -coordinated R&D programs, including the National River Health Program (1993–2001), the Environmental Water Allocation Program (2001–2009) and the Tropical Rivers and Coastal Knowledge Consortium (TRaCK) (Campbell & Schofield, 2007).

The National Program for Sustainable Irrigation also supported the COAG commitments, focusing R&D on opportunities for improving the efficiency and environmental performance of water-intensive industries (Raine et al., 2005). This efficiency focus was a fundamental shift, because for most of the 20th century water resource policy was supply focused, through construction of dams, reservoirs and weirs (Alexandra, 2018).

With its high-value, reliable production, irrigated agriculture produces approximately half of Australia's farm gate profit, mostly from the Murray-Darling Basin (NLWRA, 2002a). This productivity has inspired numerous schemes for developing northern Australia's rivers for irrigation. These rise to prominence repeatedly (Davidson, 1966 & 1969), especially during droughts in southern Australia, despite stated commitments to environmentally sound and economically rational policies (COAG, 2004), and warnings about poor soils, hostile climates and inadequate infrastructure (Connors, 2019). More importantly, other forms of economic development are likely to be more socially advantageous, internationally competitive and culturally appropriate (Hill et al., 2007; Connors, 2019).

LWA's support for R&D on northern Australia, including through TRaCK, has been important in drawing attention to these rivers' biological and cultural values (see, for example, NESP 2019a,b). These programs have led to a greater understanding of the severe constraints to irrigation development, helping to inform policy debates about risks and to articulate opportunities for innovative ways of sustaining nature, industry and culture in Australia's north (Hill et al., 2007; Connors, 2019).

Fundamental debates about the merits of large-scale irrigation development continue, with a topical example provided by Western Australia's Fitzroy River. Large-scale irrigation proposals motivated the Fitzroy River Declaration (MRFC, 2019) and the Fitzroy River Statement (Moritz et al., 2019), indicating that recognition of Indigenous rights to govern decisions about water resources remains a pressing social justice issue (Jackson & Altman, 2009; MFRC, 2019).

These debates emphasise the value of rigorous R&D in generating quality-assured, peer-reviewed information that can support informed public debate and policy development. However, high-quality, independent science capable of informing water policy remains challenging in Australia's highly politicised and heavily contested policy environment (Alexandra, 2018; Grafton, 2019). These pressures emphasise the importance of R&D funding bodies, like LWA, that through statutory independence were able to support impartial research into matters of national significance (Campbell & Schofield, 2007).

## A LEGACY OF NATIVE VEGETATION CONSERVATION

LWA R&D on Australia's native vegetation spanned the continent, from studying remnants in agricultural landscapes to the vast woodlands and grasslands beyond the agricultural fringes (Lindenmayer et al., 2008; Douglass et al., 2011).

LWA's R&D influenced the large-scale adoption of practical and policy outcomes. Since the 1990s, most Australian states have regulated broad-scale clearing of native vegetation, with regulation often accompanied by incentives to enhance conservation management. LWA contributed to the design of incentive mechanisms (Binning & Young, 1997). Similarly, R&D on savanna burning has contributed to implementing large-scale, carbon-funded fire regimes that lower $CO_2$ emissions whilst improving cultural and conservation outcomes (Douglass et al., 2011).

Responding to the need for science-based principles

to guide conservation practice, LWA supported the refinement and articulation of guiding principles for landscape conservation (Lindenmayer et al., 2008). These principles are documented in several publications, including: *Managing and designing landscapes for conservation: moving from perspectives to principles* (Hobbs & Lindenmayer, 2007); *The Bowral Checklist – A framework for ecological management of landscapes* (Lindemayer & Salt, 2008); and a paper in *Ecology Letters* (Lindenmayer et al., 2008).

## A LEGACY OF INSPIRED COMMUNICATION

LWA's publications articulated the ideal that landscapes had room for people and nature, for conservation and production and for integrating economic and cultural activities. LWA delivered loads of scientific and technical advice, via publications and websites that documented, transferred and enlightened Australia's NRM practice and enhanced capabilities. Perhaps more importantly, LWA inspired communications that tapped into a deep vein of commitment to sustainability. LWA communications complemented its technical and scientific innovations. Rigorous technical knowledge was coupled with digestible material that supported those searching for data, guidance, technical manuals, and knowhow.

Many publications are colourful and inspiring benchmarks of effective science communication, using photos, diagrams and visual art to convey meaning. That LWA commissioned and used paintings in its publications is not surprising, given that it is through the visual arts that the power and richness of Australian landscapes are often conveyed (Alexandra & Campbell, 2002). On my bookshelf several colourful bindings stand out, including the golden artwork covering *Principles for riparian land management* (Lovett & Price, 2007).

The publication *Investing in our landscapes – an assessment of the benefits of LWA research* (LWA, 2005) documents evaluations of R&D on rivers, climate forecasting, controlled traffic cropping, cleaning up cotton pesticides, salinity and irrigation efficiency. It illustrates the value of systematically designing and evaluating R&D, and provides insight into the power of using a framework of rational analysis to guide R&D on applied solutions. These evaluations illustrate the value of R&D in reversing land degradation and resolving other sustainability dilemmas. They also emphasise the importance of dedicated, independent agencies with roles in prioritising, designing and funding R&D programs.

## A LEGACY OF EVIDENCE – THE AUDIT OF A NATIONAL LANDSCAPE CRISIS

"The incorporation of ecological sustainability into policy has been ad hoc, incomplete and tentative. The central problem is that Australian governments have yet to put in place a comprehensive, integrated and far sighted way of promoting the ecologically sustainable management of natural resources" (Industry Commission, 1998).

Australia has a continental landscape crisis with symptoms that include the deteriorating condition of rivers, estuaries and near-coastal waters; the numbers of threatened and endangered species; and extensive land degradation (NLWRA, 2001, 2002a,b,c).

LWA brought together divergent information on the condition of Australia's landscapes, to deliver the National Land and Water Resources Audit (NLWRA, 2001, 2002a,b). This comprehensive assessment of the condition of rivers, catchments and estuaries, agricultural land, rangelands and biodiversity remains the benchmark of a status report on the continent which, unfortunately, comprehensively documents Australia's continental-scale landscape crisis (NLWRA, 2001, 2002a,b,c).

However, simply bringing forward this evidence is not enough to shift dominant policy paradigms. Objective assessments of the biophysical conditions, while fundamentally useful for informing policy, need to be complemented by a deeper sense of Australia's policy history and the implicit values embedded in our policy settings (Alexandra, 2018). This understanding needs to support the design of reforms to policies and the institutional arrangements that empower them.

The work of organisations like LWA can inform and reinforce the resetting of policy directions. LWA demonstrated that ambitions for transformative policies could be grounded and guided with quality analysis of options, often co-produced with industry. Thus, the R&D did not just provide evidence of problems but was focused on offering feasible solutions. Amplifying investment into salient, relevant and purposeful R&D is needed for dealing with the complex and converging Anthropocene challenges (Ison et al., 2018).

## A CONTESTED HISTORY

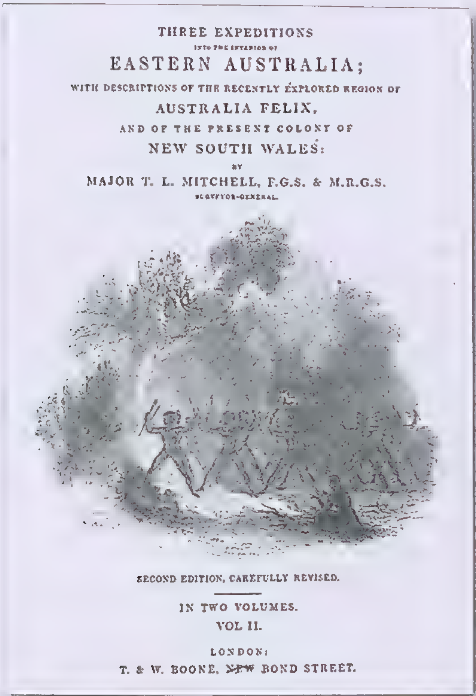
For over a century, policies for managing Australia's natural resources have been subject to a sustained contest between boosters, those backing 'Australia unlimited' – who subscribe to the view of unconstrained abundance – and those whose believe in natural constraints to settlement and production

(Strange & Bashford, 2008). For example, Griffith Taylor (1940) argued that government schemes to settle the inland and north were destined to failure due to constraints of climate and geography, and that the population would inevitability move to more hospitable, coastal regions. Australia's demographics trends – with population growth along the coastal belts – demonstrate the accuracy of Taylor's insights (Salt, 2004).

Visions of what is deemed possible in terms of agricultural development depend on the observer's bias, and the seasonal conditions they encounter during surveys. Contrasting visions are illustrated with two accounts from 1836:

> The soil in these grassy flats was of the richest description: indeed the whole of the country seemed capable of being converted into good wheat land, and of being easily irrigated, at any time by the river … the genial southern breeze played over the reedy flats, which one day might be converted into clover-fields (Mitchell, 1836).

FIGURE 1. Cover of Mitchell's 1836 publication *Australia Felix: Three Expeditions Into the Interior of Eastern Australia*


THREE EXPEDITIONS
INTO THE INTERIOR OF
EASTERN AUSTRALIA;
WITH DESCRIPTIONS OF THE RECENTLY EXPLORED REGION OF
AUSTRALIA FELIX,
AND OF THE PRESENT COLONY OF
NEW SOUTH WALES:
BY
MAJOR T. L. MITCHELL, F.G.S. & M.R.G.S.
SURVEYOR-GENERAL.

SECOND EDITION, CAREFULLY REVISED.
IN TWO VOLUMES.
VOL II.
LONDON:
T. & W. BOONE, NEW BOND STREET.

Charles Darwin's observations are in stark contrast to Mitchell's pastoral optimism. He visited New South Wales in 1836 and after "an uncomfortable tramp over the Blue Mountains in a heat wave", he concluded that Australia could never become another America – its soil was too poor, its rains too unpredictable. Instead it must depend on becoming "the centre of commerce for the southern hemisphere and perhaps on her future manufactories" (McCalman, 2002).

Despite this advice, successive governments have sought to develop intensive agricultural production, sponsoring closer settlement and irrigation development (Alexandra, 2018). Dreams of taming rivers, greening deserts and making land productive run deep in the national psyche (Lines, 1994), with political commitments to agricultural development withstanding punishing droughts and misconceptions about the severity of the natural constraints (Taylor, 1940; Connor, 2019).

Agriculture's environmental impacts have resulted in substantial economic costs through salinity, loss of biodiversity and declining water quality (Industry Commission, 1998). The sizable direct and off-site environmental impacts include the poor condition of many rivers and the eutrophication and sedimentation of near-coastal waters, including the Great Barrier Reef. These degradation problems and their severe ecological consequences have been extensively documented (SoE, 1996, 2001, 2006; NLWRA, 2001, 2002a,b,c). While the degradation of the environment became unacceptable to the public (Cullen, 1997), these "wicked problems" are systemic, persistent, and resistant to simple policy prescriptions (APSC, 2007).

In the sustained policy debates between boosterism and ecological determinism, both camps seem to have an irrepressible capacity to emerge at opportune times, advocating more irrigation development or arguing that Australia is over-populated due to water shortages. Both camps seem to be immune to the facts about Australia's highly variable climate and high per-capita water resources.

Through the use of quality, applied science, LWA brought some objectivity and insights into these debates. For example, the Climate Variability R&D Program provided excellent frameworks for understanding and responding to Australia's inherent variability. Subsequent climate science built on this, furthering the understanding of the drivers of the climate systems, and how these are responding to climate change (CSIRO, 2010, 2012).

## A LEGACY OF IDEAS – RETHINKING THE NATION

LWA contributed to broadening thinking about Australia's natural resources. For example, the Social and Institutional Research Program (SIRP) invested over $12 million in policy-relevant, social and institutional research, encouraging involvement of researchers from different disciplines – including social scientists, historians and landuse planners.

Over time, LWA explicitly recognised that regions and resources are culturally defined (Alexandra, 2017) and that therefore attention is needed to recognise living, cultural relationships to country. This shift encouraged researchers to move beyond a narrow, 'colonial' definition of resources, which privileges those valued primarily through monetary exchange, to broader definitions of value (Gibbs, 2009). These include the non-monetary economy and recognition that the nation is enriched through people's lifestyles and intimate, lived experiences of country, including those of Indigenous People.

LWA brought multi-stakeholder networks together. These provided opportunities to share understanding with the people who work with, lived in and managed landscapes, without condemning them, in any way, to simple stereotypes. It celebrated these diverse relationships as both modern and enduring – part of our legacy of continuity and change in a peopled landscape with deep history (Griffiths & Russell, 2018).

The Wik and Mabo Decisions of the High Court changed Australia's identity. These, and subsequent legislation, established native title as law, confirmed the limitation of tenure granted by pastoral leases and demolished the legal fiction of 'terra nullius' that had infected Australia for nearly 200 years (Brennan, 2006). Indigenous Australians now own and manage over 25% of the Australian landmass, including the majority of the coastline between Broome and Cape York, with considerable opportunities for diverse enterprise development (Alexandra & Stanley, 2007). They also co-manage significant national parks, such as Kakadu and Uluru. It is clear that NRM is a cultural activity because "all Australian landscapes are cultural – in that they have been fashioned by the numerous choices of countless generations, including ours. These landscapes are interpreted and reinterpreted through the lens of our culture. Both belief and physical landscapes are formed by cultures working on or with nature (and nature working on culture) and understood through frameworks of belief and cultural understanding that continue to evolve and adapt" (Alexandra & Campbell, 2002).

Sustainable resource management is often narrowly defined as the ability to sustain production in the longer term. LWA broadened interpretations of societies' relationships to landscapes by funding research exploring the celebration of cultural connections to country. It did not place these connections in 'cultural museums', but instead actively investigated living, working cultures – including those of modern woolgrowers and remote Indigenous communities. This broader perspective reinforced a more dynamic view of natural resource management, giving recognition to the fact that it is people who live in, manage, work on, understand and celebrate landscapes.

There is value in thinking about Australia's diverse landscapes in different ways and adopting new approaches to old problems. The R&D on strengthening a conservation and cultural economy for northern Australia explored alternative economic futures for the continent's north that are people focused and multifunctional (Hill et al., 2007). To genuinely explore these possibilities in keeping with the potential offered by our multicultural country, we need to redefine our cultural connectivity to country, moving beyond stereotypes of pastoralist, miner or 'noble savage'.

The examination of property rights regimes reveals much about a country and its system of governance. LWA funded R&D that examined property rights regimes for land and water and their impact on sustainable resource management. For example, Hill et al. (2007) argue that all resources are culturally defined, and that access to and ownership of resources are politically, historically and institutionally defined. Therefore, all NRM operates in deeply political and socialised contexts that are not value neutral. The prioritisation and distribution of research funds are also not neutral. This is another reason for funding arrangements that are transparent and place these decisions at arm's length from the executive government.

## A LEGACY OF INSTITUTIONAL DESIGN

LWA investigated questions about institutions for adaptive governance of natural resources. Certain 'design' features or arrangements maximise chances of success because institutional arrangements have a significant bearing on NRM outcomes (Abel et al., 2016; Hasselmann, 2018; Hassenforder & Barone, 2018). However, Australia can reasonably be defined as a contested landscape where deep tensions remain about policies, paradigms, priorities and objectives, with any arrangements negotiating these tensions

(Alexandra, 2018; Grafton, 2019). Overarching questions about the kinds of institutional arrangements needed include:

(i) How can rigorous science best support policy decisions?
(ii) What governance systems enable transparency and accountability?
(iii) What mechanisms can ensure scientific independence?

Natural resource policies and programs need to be able to attribute their impacts and effectiveness. However, the impacts of Australia's NRM programs have been difficult to quantify reliably (Campbell et al., 2018), drawing attention to the need for independent and scientifically credible monitoring of environmental trends (NLWRA, 2001, 2002a,b; SoE, 2006). Furthermore, these assessments need to be integrated, assessing environmental conditions in a holistic way, in order to guide policy settings and to ensure greater accountability of the government agencies responsible (NLWRA, 2006).

LWA furthered the ideal of integration of conservation and production in diverse landscapes, legitimising new approaches to the problems of working in an ancient landscape. It helped to refine production systems, working with industry on improving irrigation efficiency, reducing pesticide impacts and forecasting future climatic conditions (see LWA, 2005). Its R&D generated and promoted practices, incentives and innovations that will have productive impacts for decades, including in intensive plantation forestry (Lindenmayer et al., 2003), revegetation and agroforestry (Alexandra & Campbell, 2002; JVAP, 2002) and the continent's vast savanna ecosystems (Douglass et al., 2011).

It is near impossible to measure accurately the full extent of LWA's impacts, but without its work, it is likely many practical and policy-orientated solutions would not have been adopted.

## EVALUATING LWA'S IMPACTS

Successive Australian governments have espoused policies that explicitly aim to deliver ecological sustainability and promote environmental stewardship. National policies include the COAG water reforms (1994 & 2004), the Decade of Landcare Plan, National Water Quality Management Strategy, and the National Strategy for the Conservation of Australia's Biodiversity (Commonwealth of Australia, 1990, 1992, 1996). There are numerous corresponding state policies and regional plans (Curtis et al., 2014; Abel et al., 2009; Campbell, 2018). Collectively, these reflect a vision for living well in this ancient continent and give expression to communities' desire for more sustainable management of the country and its natural heritage (WWF, 2002; Alexandra & Riddington, 2006). Likewise, local landcare efforts give practical effect to these sentiments (Campbell, 1994; Marriot et al., 1999; Campbell et al., 2018).

It is always difficult to accurately attribute what R&D contributed, and the degree to which any specific R&D enabled, reinforced, motivated or reflected these wider social changes. Nonetheless, LWA regularly and rigorously evaluated its programs, adopting robust systems for evaluating the impacts and effectiveness of its work. Its evaluations asked and found ways of answering the question: how did the generation and communication of knowledge effect change (LWA, 2005; Campbell, 2006; Campbell & Schofield, 2007)?

Furthermore, it is almost impossible to specify what the abolition of LWA has cost Australia in the lack of coordination and strategic investment in public-good R&D. However, given the ongoing contestation and disputation about land and water policies, and the need for science to inform these policies, an agency like LWA is sorely lacking from Australia's current institutional framework.

## LWA'S DEFINING CHARACTERISTICS

In *The Getting of Knowledge*, Campbell and Schofield (2007) examine LWA's strategic and systematic approach to R&D program design. Likewise, in *The Australian NRM Knowledge System*, Campbell (2006) outlines principles for intelligent R&D investments, arguing that it is critical to focus effort and attention on asking the right questions, and to selecting R&D likely to have enduring impacts. Adopting these approaches, LWA strategically invested in generating applied results, but was not bound to any particular modes or methods of R&D, nor to sustaining any specific organisation. It was not required to support any specific disciplinary approach, research agency or problem-solving paradigm, because the legislation enabled discretion in prioritising and allocating R&D funds, so long as those decisions aligned with the strategic five-year plan. As a result, R&D programs drew on and combined the capabilities provided by researchers in the humanities and the social and natural sciences from governments, universities and the private sector. LWA recognised it is people

who make things happen, becoming a network of networks, of linkages and relationships that spanned the continent.

LWA's defining characteristics were:

(i) discipline in scoping significant issues and opportunities for R&D in the public interest;
(ii) rigour in analysis about what would yield to research;
(iii) a focus on research with durable impact;
(iv) a willingness to innovate in developing Australian solutions to Australian problems;
(v) pragmatism about leveraging modest financial resources through building alliances, partnerships and networks; and
(vi) a willingness to invest in people – through fellowships and scholarships, and through its staff and coordinators.

The institutional arrangements that contributed to LWA's successes included:

(i) a legislated clarity of purpose – a sustainability mission aligned with the public good;
(ii) a broad mandate but with significant discretion in allocating R&D funds according to clear principles;
(iii) statutorily defined independence; and
(iv) bespoke program governance and management systems, including communications and engagement on shared challenges.

In terms of independence from political directions, LWA's statutory independence was an important feature. Under the PIERD Act, the Minister and the Department could direct LWA only by way of written advice, particularly through advice on its five-year strategic plans. Therefore, any attempts to direct how priorities were set and R&D funds allocated were on the public record and subject to external scrutiny.

## GENERIC LESSONS FROM THE LWA MODEL – NRM IN A CHANGING WORLD

NRM is a global sustainability challenge due to the pressing need to decouple production, resource use and pollution intensity (Campbell, 2006). Biodiversity conservation, water and land use, food and energy production and carbon intensity are converging 21st-century challenges, sometimes referred to as global limits or planetary boundaries (Rockström et al., 2009). There are compelling arguments that innovative, scalable solutions are needed, particularly given a growing global population, and constraints to land, water and energy use (Weaver et al., 2000; Pahl-Wostl, 2017).

Sustainability imperatives demand technical and policy innovation, in order to innovate the way we undertake R&D (Weaver et al., 2000). Transformations of agriculture and NRM require integrated responses including systemically redesigning and revitalising R&D systems (Andersson & Sumberg, 2017), particularly in light of the increasing uncertainty induced by climate changes (Alexandra, 2012). R&D should be one of the powerhouses of sustainability transformation, but this requires effective institutions for innovation that are often characterised by boundary-spanning relationships and multi-scalar networks (Cash, 2001; Cash et al., 2003).

Sustainability science "demands integrated and at times radical approaches to complex problems. Sustainability science plays critical roles in articulating preferred futures and in developing smart ways to create these futures" (Alexandra & Campbell, 2002). Yet many established institutional models and governance paradigms appear ill-equipped to deal with Anthropocene challenges (Ison et al., 2018). Resources and creativity need to be focused on social, technical and governance innovations (Weaver et al., 2000).

So what generic lessons can be extracted from the LWA model?

LWA's approaches evolved to have an explicit focus on integrating the technical, human, policy and social aspects of NRM. R&D programs focused on the complex dynamics between scientific understanding, public policy and social change, including on pathways to achieving adoption (Campbell, 2006).

LWA demonstrated that R&D could be a powerful instrument in tackling the "wicked problems" plaguing sustainability (APSC, 2007) when funds are allocated by skills-based boards, granted statutory independence (Campbell & Schofield, 2007).

LWA demonstrated that with focus, discipline and skill, R&D funds could be directed to national priorities. This experience provides some useful and important lessons for developing integrated solutions (Campbell, 2006). Solutions to the challenges of becoming a more sustainable society are unlikely to be found by funding science randomly (Cash et al., 2003). So governments and multilateral organisations could apply the 'LWA model' to driving the innovations needed for accelerating transformations.

There has been much speculation on what led to LWA's abolition, with numerous reasons offered. What is important to recognise is that no government agency

is immune to budget cuts and legislative change. However, it is ironic that LWA was abolished in the same year that the review of Australian public service identified the pressing need for strategic policy and innovation capacity, proposing that this be achieved by policy agencies forming long-term R&D partnerships (APSC, 2010; Ison et al., 2018) like those formulated and coordinated by LWA.

Some regard LWA's demise as a strategic blunder, rather than an example of ideology-driven bloody-mindedness. However, this seems unlikely given that the pattern of Commonwealth government departments terminating small, effective satellite agencies is well established. Terminations include the Commission for the Future, the Resource Assessment Commission, the Energy R&D Corporation and the National Water Commission (Marlow, 2019). This disturbing pattern needs further investigation in the interests of determining how to ensure better and more durable arrangements are developed in the future.

## CONCLUSION

Australia's systems of governance need to generate new wealth from our old landscapes, without destroying the priceless treasures of 600 million years of separate evolution and 60,000 years of human occupation (Alexandra & Riddington, 2006). This unique evolutionary and cultural heritage is entrusted in contemporary Australia's care. This is a burden of responsibility. Unfortunately, Australia's entrenched land degradation and failures in biodiversity conservation are sobering. The nation's capacities to deliver on conservation policy commitments are limited (NLWRA, 2002b), and the chaos of climate change will pose additional pressures and challenges (Alexandra, 2012).

LWA demonstrated that a relatively small R&D budget could drive innovation and adoption. It focused R&D on practical solutions, working with people to co-develop and deliver solutions that combined knowledge and practice (Campbell, 2006).

However, history demonstrates that knowledge is contingent and fragile. The capacity for impartial research focused on sustainability needs to be enabled through legislative processes, transparent institutions and dedicated funding. This capacity must be cultivated, nurtured, nourished and sustained because knowledge is not contained in artefacts – books, journal papers, databases, reports and communication products – but in people, who have the capacity to apply, refine, educate and teach. Institutional settings can enable or constrain these capabilities. Small, purposefully designed, boundary-spanning organisations can accelerate transformations towards sustainability.

LWA provided an important precedent for the kinds of R&D arrangements needed for tackling the 21st century's systemic problems. The Productivity Commission (2010) recommended that a new entity be established to continue public-good research, in the trajectory established by LWA. Acting on this need remains overdue and urgent. Any government could enact new legislation to create such an entity. Those of us who want to see more impartial research need to advocate such an approach.

The institutional arrangements needed for revitalising public-good R&D can draw on the insights provided by the experience of LWA. The 21st century's systemic problems require institutional innovations that can accelerate urgent sustainability transformations. Australia should pursue the creation of more entities like LWA in the States and Commonwealth. However, these do not need to be limited to rural R&D. We could have equivalent bodies focused on the transformation of our cities, our energy and transport systems, and on adapting to climate change. For these to work we need to adopt institutional designs that incorporate the best features of what has been learnt, in terms of directing R&D funding towards generating and adopting effective, policy-relevant innovations.

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# "BY SAVAGE HANDS HIS STEPS WERE STAYED!"[1] LIFE AND DEATH ON THE PERCY ISLES, 1854

ROWLAND, MICHAEL J.[2]

In October 1854, the ketch *Vision* arrived at Middle Percy Island off Mackay on the central Queensland coast. The botanist Walter Hill, naturalist Frederick Strange and crew members went ashore. Hill went off with three Aboriginal people while the crew stayed behind with six others. When Hill returned, he found the crew except Dalaipi (an Aboriginal crew member) dead. Nine Aboriginal people were later captured and sent to Sydney to be tried for the killings. They appeared before the Water Police Court in Sydney before the court ordered they be sent back to the Percy Isles, though they appear not to have made it beyond Port Curtis. The death of Strange was widely reported in newspapers across Australia and was portrayed as a clash between the "heroic explorer and scientist" and the "untutored savage". The events on the Percy Isles and further contacts on islands off the coast of central Queensland occurred from a time of limited hostile contact through a period of growing shipping movement, to a time of more substantial and lethal contact involving the Native Police. Contact events on the central Queensland coast reviewed here provide insights into reasons for initial limited hostilities on the offshore islands prior to increasing hostile and lethal conflict on mainland coastal and inland frontiers.

Keywords: Queensland, Percy Isles, Indigenous-European Contact, Frederick Strange

*[1] The title is from a poem by "G.F.A" in The Sydney Morning Herald, 4 August 1855, p. 5, titled LINES TO THE MEMORY OF THE LATE FREDE. STRANGE. (WHO WAS MURDERED BY THE NATIVES OF PERCY ISLAND.). The theme of the poem and many of the newspapers of the time contrast the "noble man of science" with the "untutored savage". "G.F.A." is George French Angas, natural history artist and Colonial Museum (now the Australian Museum) Secretary.*

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## INTRODUCTION

Maritime frontiers are places where Aboriginal and Torres Strait Islander peoples had early and often peaceful or neutral short-term encounters with seafaring outsiders, while coastal land frontiers are areas where outsiders arrived from the sea and/or land establishing permanent settlements along the coast and hinterland, resulting in increasing hostilities (McNiven, 2001). Contact events that occurred on islands of the central Queensland coast provide important examples of the processes involved, commencing with fleeting coastal European visits, progressing through more regular contact, and ending with permanent mainland settlement on adjacent mainlands. Tracing the development of these events through contemporary newspaper reports and other sources provides a picture of how amicable coastal contact developed prior to more lethal coastal and mainland conflict. The events that occurred on the islands of the central Queensland coast developed before the commencement of warfare on the mainland pastoral frontier, and prior to the full impact of the activities of the Native Police.

Prior to Aboriginal–European contact on the Percy Isles in 1854, *The Moreton Bay Courier* (Anon, 1854a, p. 2) reported that the residents of Brisbane considered Aboriginal people of the central Queensland coast and surrounding islands to be "savages". They had developed an "evil reputation" (Daly, 1887, p. 31), and Delamothe (1969, p. 6) could recall no other region of the continent where numbers of Europeans killed or wounded exceeded the number of Aboriginal casualties, though as argued below this appears to be overstated. Earlier significant attacks on Europeans had occurred in the Torres Strait on the *Charles Eaton* in 1834 (McCalman, 2013, p. 79; Ørsted-Jensen, 2011, Appendix A, p. 208), around Brisbane from first settlement in 1824 (Connors, 2015, p. 58), and at the southern

end of the Great Barrier Reef following the wreck of the *Stirling Castle* in 1836. The story of Eliza Fraser led colonists to see Aboriginal people as "violent, animalistic and sexually predatory", even though much of Fraser's story was discredited (McCalman, 2013, p. 64). Behrendt (2016, p. 54) notes that stories of "native barbarity" associated with Eliza Fraser were embellished to justify violence and dominance, and to gain support for plans to eradicate, subdue, tame, contain and control Aboriginal people. Significantly, *The Moreton Bay Courier* (Anon, 1854a, p. 2) also referred to events on the Percy Isles as murders carried out "by natives of an island near New Caledonia", suggesting that perhaps the coast and islands of Queensland were perceived as coterminous with those of the Pacific, all of which were inhabited by "savages". This view is shared with McCalman, who argues there was a popular fascination with "the sexual perversity, violence and cannibalism of South Seas natives" (McCalman, 2013, p. 67). Thus, the reputation of the Aboriginal people of the central Queensland coast may have become enmeshed without justification in this broader geographical perspective. Nevertheless, conflicts did occur within the area as Aboriginal groups began to resist the invaders, and these conflicts are investigated here to determine what causative factors were involved.

Since 1978, I have undertaken archaeological investigations on islands off the central Queensland coast (e.g. Rowland, 2008), though detailed documentary evidence of the violence and degradation to which the indigenous Keppel Islanders (Woppaburra) were subjected also became a significant focus of study. When Keith Windschuttle (2002) downplayed the role of frontier violence in Australian history, the responses from scholars and the media were numerous and wide-ranging (e.g. Attwood, 2005; Clark, 2002; Macintyre & Clark, 2003; Manne, 2003; Ørsted-Jensen, 2011). Many researchers focused on definitions and numbers of people killed, but I cautioned that what happened to the Woppaburra demonstrated that it was important to be aware of the complex human tragedy behind definitions and body counts, and that it was important to report local and regional events as individual narratives since they highlighted a level of suffering not always disclosed by broader debates (Rowland, 2004a). Aboriginal people were shot but also suffered from the impact of introduced diseases, were poisoned, sexually abused, kidnapped and used as forced labour, imprisoned and hanged, introduced to alcohol and tobacco, and dislocated from their lands and resources (Bottoms, 2013; Campbell, 2002; Evans et al., 1975; Reynolds, 2013). But Aboriginal and European people acted in very individualised ways in local and regional areas. In 1982, my archaeological focus shifted to the Percy and Whitsunday Islands (Rowland, 1984, 1986). At the time, I briefly reviewed contacts between Europeans and Aboriginal people on the islands, but access to information was limited. Now, with online access to a greater range of documents, it is possible to focus in more detail on contact events on the maritime frontier in the vicinity of the Percy and Whitsunday Islands. Again, while body counts are noted, the focus is on the human tragedies suffered on both sides of the frontier.

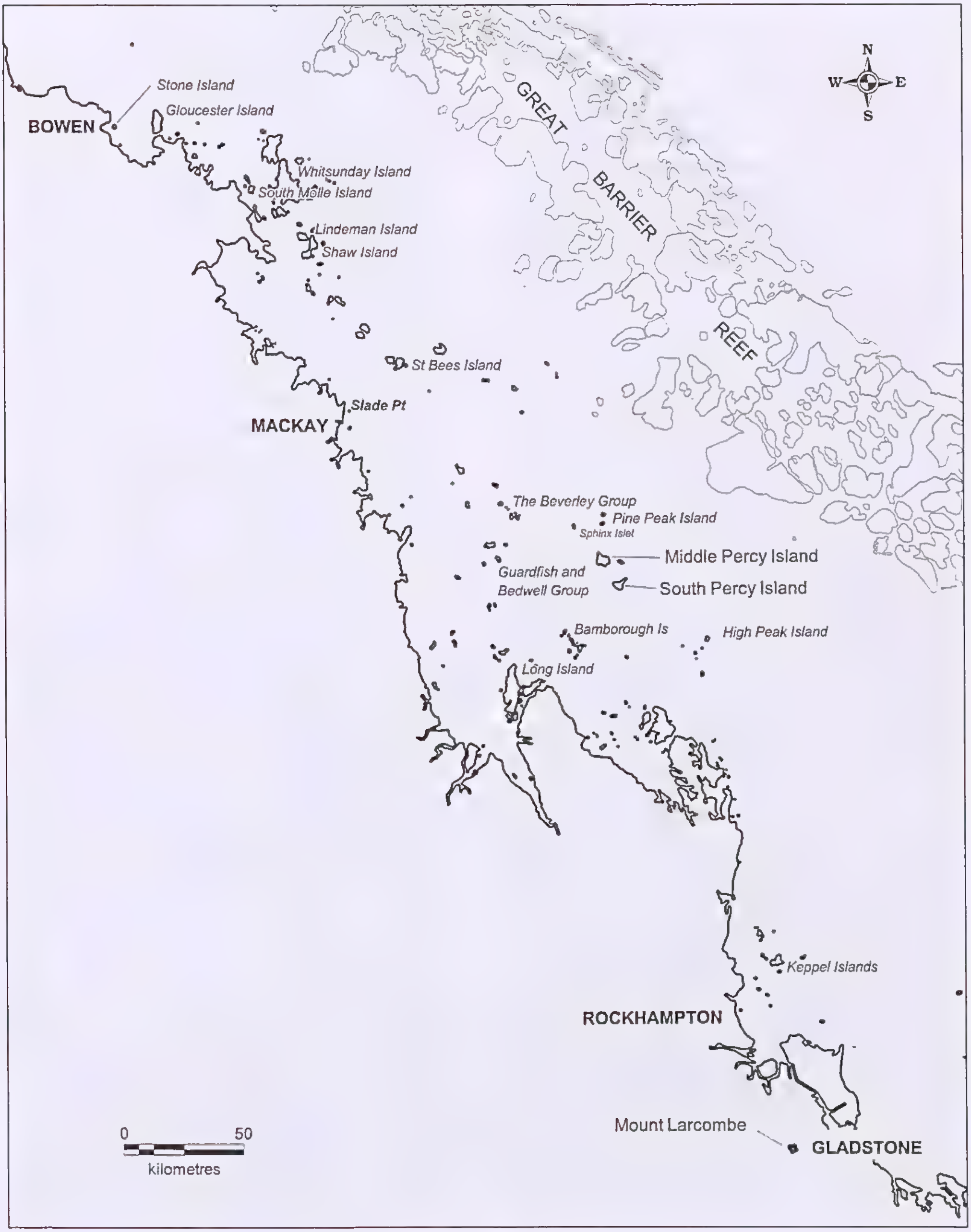
This paper complements one by Comben (2017) previously published in the *Proceedings*, but adds to and extends the scope of that paper. Comben (2017, p. 75) focused on developing a biography of Strange from disparate sources and previously conflicting information, and concludes that while Strange did not have the professional background of naturalists of that era, he succeeded, prior to his death, in becoming a "fine naturalist and Australian pioneer". Comben also outlines the events leading to Strange's death on Percy Island in 1854. In this paper I do not discuss Strange or his abilities as a naturalist, which is well covered by Comben. Rather, I outline the events that occurred on Percy Island in greater detail and discuss other cases of contact and conflict on the central Queensland coast prior to European mainland settlement. Contact events are often cited in full to maintain integrity of the narratives. It is apparent that initial conflicts along the maritime frontier may have been limited and fatalities few, a situation which changed dramatically following mainland settlement.

## THE PERCY AND WHITSUNDAY ISLANDS

The Percy Isles comprise two major islands and nine smaller ones covering a total area of about 43 km$^2$, stretching 180 km along the coast between 20° and 21.5° south latitude. They are the most distant group of islands off Australia's east coast. From Middle Percy Island it is about 125 km north-west to Mackay, 85 km to the nearest point on the mainland, and 40 km to the Guardfish and Bedwell Group of islands directly to the east. The Percy Isles are in fact closer to the outer fringes of the Great Barrier Reef (about 50 km) than to the mainland. The Whitsunday Islands comprise over 70 islands ranging in size from less than 1 hectare to over 10,000 hectares. They extend north to south over 200 km and are closer to the mainland than the Percy Isles (Barker, 2004, p. 1; Border, 1999,

pp. 129–130) (Figure 1). Given the limited watercraft technology available in the area and the distances involved, it is somewhat surprising that many of the islands were visited or occupied (Rowland, 1984).

FIGURE 1. Islands and coast of central Queensland; places mentioned in the text.



## EARLY EUROPEAN COASTAL CONTACT

The first documented 'discovery' of the Australian mainland by Europeans occurred at Cape York in 1606, which also marked the first recorded instance of Indigenous–European conflict when a crew member from the Dutch vessel *Duyfken* was fatally speared near the Wenlock River (Mulvaney, 1989, p. 8; Sutton, 2008). Following this initial contact, Lieutenant James Cook took possession of the east coast of Australia in 1770, and several explorers later observed people on the offshore islands and adjacent mainland of central Queensland; however, initial contacts were transitory and recorded details are few (Bowen & Bowen, 2002, p. 39; Pearson, 2005, pp. 15–28). Contact may have been friendly or cautious, with limited competition for land or resources.

In June 1770, Cook passed by the Percy Isles, noting them as "an indistinct landmass" (Beaglehole, 1955, p. 333). In 1802, Matthew Flinders named the Percy Isles, and while he spent about six weeks in the area, he had few contacts with Aboriginal people (Flinders, 1814, pp. 56–95). In 1812, the *Cyclops* took the inner route through the Great Barrier Reef, but no record or charts of the voyage exist (Pearson, 2005, p. 95). In 1815, Charles Jeffreys on the *Kangaroo* charted the inner route but bypassed the islands. By this time the whale and seal trades were both flourishing, while merchant ships and transports were going to India from Port Jackson (Bowen & Bowen, 2002, pp. 78–80). Phillip Parker King's survey of the coast was initiated due to the increasing number of vessels using the inner-coastal route. In June 1819, King anchored the *Mermaid* at West Bay on Middle Percy Island and commented that "Tracks of natives, but not of recent date were noticed" (King, 1827, p. 184). King returned to the Percy Isles in June 1821 but made no mention of Aboriginal inhabitants, and he moved rapidly through the reef noting "native fires" on a number of the Whitsunday Islands (King, 1827, p. 8). Following the mapping of the coast by King, four more hydrographic surveys were undertaken. The first, in June 1841 on the *Beagle* commanded by John Lort Stokes, passed by the Percy Isles but made no detailed observations (Stokes, 1846, pp. 327–328). The *Fly*, supported by the *Bramble*, spent eight months surveying the Reef. In February 1843, the *Fly* sailed through the Percy Isles, but no observations were made of Aboriginal inhabitants on either the Percy or Whitsunday Islands (Bowen & Bowen, 2002, p. 89: Jukes, 1847, Vol. 2, p. 264). In 1847, the brig *Phantom* passed by the Percy Isles where native fires were seen, and later Shaw Island where numerous fires were also noted (Anon, 1846, p. 4). In December 1847, the *Rattlesnake*, under the command of Captain Owen Stanley, anchored off Middle Percy Island, and MacGillivray, the naturalist, noted the presence of fire-places but none were recent. Significantly, it was reported that:

> … the bush was thoughtlessly set on fire by some of our people, and continued burning for several days, until nearly the whole island had been passed over; the long grass and dead trees blazing very fiercely under the influence of a high wind (MacGillivray, 1852, p. 60).

In April 1849, the *Freak*, commanded by T. Beckford Simpson, and the *Harbinger* anchored in the lee of Middle Percy Island, where they found two men named Clarke and Davis on the island. The men claimed to be shipwrecked from the schooner *Bona Vista* on a *beche-le-mer* voyage to Torres Strait. However, conflicting statements given by the men led Simpson and Carron to suspect that they were escaped prisoners from either Hobart Town or Launceston. Simpson and Carron were correct in this assessment. The four men were John Hill, John King, Rees Griffiths and Matthew Clarke, who had escaped from Tasmania in the *Psyche*, a small yacht owned by the Bishop of Tasmania (Anon, 1949a, p. 3).

Clarke later claimed that the *Bona Vista* left Port Nicholson in New Zealand in February, became stuck on a reef and was holed. A raft was made of the vessel's spars and they landed on a number of islands before arriving on Middle Percy Island, where they claimed to have been for about three weeks and "have had nothing to eat during that time but small oysters and winkles". One of their companions died and was buried on one of the islands (Carron, 1849, pp. 102–103). John Davis claimed that on the islands nearer the mainland [probably the Beverley Group] they had "a side-out with the natives" (Carron, 1849, p. 104). In 1852, the *Herald* undertook a new survey within the area and, in 1859, sailed on a second survey lasting six months, in which a visit was made to the Percy Isles to replenish water supplies. Unfortunately, very little was published concerning these voyages (Bowen & Bowen, 2002, pp. 105–106).

In sum, despite conflict occurring as early as 1606 on Cape York, and significant and ongoing conflict at Moreton Bay from 1824, little conflict appears to have occurred on islands of the central Queensland coast until the arrival of the *Vision* in 1854. Some explorers passed rapidly through the area (e.g. Cook),

though others (e.g. Flinders) spent nearly six weeks in the region but made little contact with Aboriginal people (or at least little was reported), though evidence of their presence was commonly observed. The inhabitants of the islands may have hidden from the explorers as they did on the Keppel Islands, with women in particular being shielded from Europeans (Rowland, 2004a, p. 12). It is also likely that not all islands were occupied on a permanent basis, lessening the chance of contact. Lesser-known explorers were in the area from at least 1797, and by 1802 whalers, sealers and other traders were taking the inner route through the Great Barrier Reef. By the time King had completed his surveys of the coast in 1822, at least 11 ships had been lost in reef waters, and in the ensuing decades up to 1861, some 148 further losses were officially recorded between Moreton Bay and Torres Strait (Bowen & Bowen, 2002, p. 86). The impact of surviving crews on the inhabitants of the coast and islands may have been significant but will probably remain unknown. The number of survivors of shipwrecks and runaway convicts was significant; only some of them made their way back to established European settlements on the mainland. The seeds of potential conflict at this early stage are not clear. Middle Percy Island was identified as an important source of potable water, which might therefore have been a source of competition. In 1847, Middle Percy Island was set alight by MacGillivray's crew, which would have reduced the island's resources and caused great offence to the islanders. Finally, in 1849, the convicts Clarke and Davis subsisted in the area for as long as three weeks, and at least one of their group died and was buried on Middle Percy Island. They also had a "side-out" with a group on one of the islands. The perspectives of neither the European nor Aboriginal participants in these early engagements can be abstracted from the available sources.

## THE VISIT OF THE *VISION* TO THE PERCY ISLES IN 1854

The visit of the *Vision* to the Percy Isles in 1854 is the first contact event in the area where there are detailed records, and these events are reviewed in detail here as they give an insight into the causes of conflict. My original summaries of European exploration and contact throughout the islands of central Queensland were limited to brief reviews as background to archaeological investigations (Rowland, 1984, 1986). Access to online newspapers now provides a broader perspective on European–Aboriginal contact in the area (in particular Trove online at http://trove.nla.gov.au/). Contemporary newspaper reports often provide more comprehensive coverage than official archive papers, and I have used them extensively. Ørsted-Jensen (2011) has undertaken a comprehensive search of newspapers and government sources relating to contact events in Queensland. In relation to the attack on the *Vision*, however, Ørsted-Jensen provides only three references and a very brief account, but as demonstrated below, considerably more information is available.

Frederick Strange purchased the *Vision* for the purpose of collecting specimens of natural history and left Brisbane on 12 September 1854, returning on 14 November after an attack on her passengers and "murder of some of them by natives of an island *near New Caledonia*" (my emphasis) (Anon, 1854a, p. 2). The captain was George Elphinstone Maitland, and the crew consisted of William Spurling, mate; William Vann, able seaman; Jeffrey Gray, ordinary seaman; and Andrew Gittings, cook and steward. The passengers were naturalist Frederick Strange and his assistant Richard Spinks; Walter Hill, botanist; and Deliape, an Aboriginal man whom they took on board at Moreton Island (see Comben, 2017, for a biography of Strange). Walter Hill was born on 31 December 1819, at Scotsdyke, Dumfriesshire, Scotland. He and his wife arrived in Sydney in 1852. He was chosen as first superintendent of the Botanic Gardens in Brisbane in 1855. When Queensland became a separate colony in 1859, he was appointed colonial botanist. He retired in 1881 and died in 1904 (McKinnon, 2013). There are different versions of the spelling of Deliapi in newspaper accounts. He is "Dalaipi" referred to favourably by Thomas Petrie (see Petrie, 1904 [1980], Chapter 21). I use Petrie's spelling except where quoting directly. *The Moreton Bay Courier* notes that on return, Delaipi left the vessel at Moreton Bay to re-join his tribe (Anon, 1854a, p. 2). His role as an intermediary in events on the Percy Isles remains obscure (Kennedy, 2013, Chapter 6).

On 14 October 1854 the *Vision* anchored at Percy Island, and on the following morning Strange, Spinks, Spurling, Gittings and Dalaipi landed on Middle Percy Island and went inland in search of water. On returning, they made contact with nine Aboriginal people and gave them fishhooks and tobacco. Another group of about 12 Aboriginal people was seen in the hills. Hill then went off to explore the "mountains". On returning, he observed:

> … a body among the mangroves, and on examination, he found it was Spurling. He was quite dead:

having received a cut on the left side of his neck, from which much blood had issued, as well as from the nostrils:— he was naked; his clothes and boots having been taken away. He thought the wound might have been inflicted by a boomerang. … Deliape came to him in a state of great excitement, and in answer to a question respecting Mr. Strange, said one of the natives had speared him in the thigh, and he (Mr. S), as soon as he had extracted the spear, shot one of the blackfellows, the natives then closed upon them, and commenced waddying Spinks and Gittings, and threw a spear at him (Deliape), but he ran away and escaped. They got aboard, but saw nothing more of the rest of the party. They did not land to search for those who were missing, because they had not sufficient strength—two of their crew having been seized with the meazles [*sic*], and Deliape would not go ashore again. There was therefore only himself (witness) [Hill] and the captain. They fired several volleys of musketry next day, but it was not answered. On the 16th May [*sic*], weighed anchor and beat about the Island; on the 25th they observed a large fire. They arrived at Moreton Bay on the 13th November … He [Hill] identified two of the prisoners, as having been among those who were left with Spurling when he had charge of the boat (Anon, 1854a, p. 2; Anon, 1855a, p. 4).

FIGURE 2. Walter Hill. Courtesy State Library of Queensland and John Oxley Library.

FIGURE 3. Frederick Strange. Papers of Gregory M. Mathews 1900–1949. Courtesy National Library of Australia.

In response to Hill's evidence, the *Courier* noted:

> Notwithstanding that the very worst may be conjectured from the foregoing narrative, still it is to be hoped, that the search will not thus be given up, while there is the remotest chance of some of the missing men being alive. It is impossible to re read this account without a feeling of disgust for the pusillanimity of those who refused, although no doubt having the means of fully arming themselves, to go on shore and resume the search on the morning after the supposed murder (Anon, 1854a, p. 2).

The search for possible survivors became a political issue, entangled with attempts to rescue survivors from the wreck of another ship, the *Ningpo* at Guadalcanal in the Solomon Islands, and with conditions and the rule of law at Moreton Bay. Consideration of resources for rescues over such a large area of north Queensland and areas of the Pacific led to calls for a steamer to be based at Moreton Bay or Port Curtis, along with a coal depot to facilitate search and rescue from those locations (Anon, 1854b, p. 5).

A number of references were also made to the savagery of Aboriginal people on this part of the coast.

The Sydney correspondent of *The Argus*, for example, noted:

> I have little hope for poor Mr. Strange, for the Percy Islanders are of the same race as the people of North-eastern Australia, perhaps the most degraded set of savages on the face of the earth, who have no other tomb for the dead, in any case, but the stomachs of the living (Anon, 1855b, p. 4).

Evidence that the Aboriginal people of north-eastern Australia (or indeed Australia in general) indulged in cannibalism as implied by *The Argus* is rare if not non-existent, but was exaggerated in order to subdue Aboriginal people (Behrendt, 2016, Chapter 6).

On 29 December 1854, the government despatched the *Torch* with large quantities of trade, to induce the islanders to release Strange and his party if still alive (Anon, 1854c, p. 4).

A substantial account of what happened to Frederick Strange and his party, and the subsequent capture of those allegedly responsible, is contained in a report of 12 March 1855 by the captain of *HMS Torch*, William Chimmo. Chimmo reached Middle Percy Island on 29 January and immediately sent an armed party, under Francis Hixson, Acting Second Master, to search the island. His instructions to Hixson included: "... you will avoid as much as possible any unfriendly act, but treat them in the kindest manner" (Chimmo, 1855). The party returned to the *Torch* at sunset without success. At daylight, eight Aboriginal people appeared on the beach, armed with spears, waddies and boomerangs. Chimmo then issued orders to Hixson that: "Not one word is to be mentioned as to the real object of our visit, our only hope of recovering the dead bodies of our countrymen, being *stratagem*" (Chimmo, 1855, p. 15). The islanders were given pipes, tobacco, fishhooks and other presents, but when Chimmo proceeded up the creek to the scene of the murders, they disappeared. In the evening, Chimmo sent an armed party to search a few bark huts in the interior, but they returned without success. On 31 January, Chimmo sent a crew to search the mangrove swamp. At sunset the party returned, having found among the mangroves, half buried in the mud, the remains of Spurling. The bodies of Strange, Spinks and Gittings were not recovered, as they had apparently been thrown into the sea. John D. Macdonald, Assistant Surgeon, provided a detailed report on Spurling's remains, from which Chimmo concluded that his death "must have been an awful one, as his skull shews, lower jaw broken on one side, right side of skull entirely smashed, left leg altogether gone". A canoe was seen with a paddle in it, and this was seized and destroyed (Chimmo, 1855, p. 15). Chimmo noted: "I could not leave this horde of murderers without an attempt to capture them, and bring them to justice." He therefore ordered Hixson and 25 armed men to carry out a search of the island. These orders included ominously: "If they run away, they must take the consequences." There is some ambiguity in the instructions, since Chimmo also advised that: "Endeavour to perform this service without firing a musket (it will redound much more to our credit if we do so), and only use your arms in your own defence" (Chimmo, 1855, p. 16).

Subsequently, Hixson landed with the 22 men but succeeded in capturing only nine individuals (two men, three women, and four children), while three men escaped. Two men were later seen on the beach, but they also escaped. Four canoes were destroyed. Hixson sent the prisoners to the *Torch* while he and the crew went in search of the other men, but again without success. The men made a number of attempts to escape. On 5 February, Chimmo landed 33 armed men on the island. The party later returned, having scoured the island without locating any inhabitants. Chimmo found satisfaction in knowing that there was not a living person on the island and that:

> ... this will be the last endeavour *by us* to rid this island of one of the most treacherous bands of murderers that could possibly disgrace the face of the earth. It is therefore sincerely to be hoped that not *one* will be left to retaliate this their retribution on any persons, who may hereafter visit this island (Chimmo, 1855, pp. 16–17).

Chimmo arrived at Port Curtis on 7 February, where he thought it important to make an impressive ceremony of interring the remains of Spurling in the Christian burial ground. Captain M. C. O'Connell, the Government Resident at Port Curtis, noted:

> I shall be glad on this melancholy occasion to afford all the assistance it is in my power to give, to make impressive a ceremonial which may lead even the untutored savage to comprehend the vastness and energy of the protective power which watches over Her Majesty's subjects (Chimmo, 1855, p. 19).

However, the outcome was contrary to expectations. It appears that Aboriginal people from around

Gladstone were aware of the Percy Islanders being captured, and a large and angry gathering was apparently about to descend on Gladstone to carry out revenge – the rumoured attack raising hysteria amongst the residents of Gladstone (McDonald, 1988, p. 22).

## THE PERCY ISLANDERS IN SYDNEY

In Sydney, the Percy Islanders appeared before the Water Police Court on a number of occasions. An initial account from *The Sydney Morning Herald* states:

> … six aborigines were placed in the dock upon suspicion of murdering Mr. Strange and others at the Percy Islands. They were accompanied by four children, apparently from two to four years of age. The Court House was cleared, and the uncivilized ladies and gentlemen were introduced – the legs of the men being fastened together with a rope. When they were shown into the dock the females walked into one corner, and the men to the other. The rope was then slackened, and one of the lords of the creation immediately seated himself comfortably in the corner to finish picking meat off a bone of large dimensions which he was assiduously gnawing with great satisfaction when he came into court. He was, however, evidently deeply interested in the proceedings, for he rose as soon as the case was proceeded with. The adults of both sexes had each been supplied with an apron, which they wore in a very careless manner. The children, however, were totally devoid of clothing. Three of them had their legs twined very affectionately round the necks of their mamas, who enabled them to preserve their seats by taking hold of their feet; the fourth, a young lady of about four summers, amused herself by standing on her toes, and peeping over the Dock at their worships, or stooping and peering through the bores at the visitors. Their knowledge of English was very limited, being confined to "Cockatoo," "Wooloomooloo," &c. One of them can say "kill white feller" very plainly, and another gives his name as Captain Moriarty (Anon, 1855c, p. 4; Hixson had reported that nine individuals were captured, whereas ten are reported in Sydney).

On their second appearance:

> The men smiled as they were placed at the bar, but maintained throughout the proceedings the utmost quietude, cowering together in one corner, their features bearing the appearance of dulness [*sic*] and inexpressiveness characteristic of the savage.
>
> The black, Deliapi, said he did not know what the cause of the blacks commencing the outrage was, but he thought *it was something about water* (my emphasis) (Anon, 1855d, p. 4).

The islanders again appeared before the Water Police Court on 3 April 1855, where Hixson indicated he had destroyed three canoes and had taken a number of clubs, boomerangs and a tomahawk off the island (Anon, 1855, p. 8). The prisoners were brought before the Water Police Court finally on 10 April 1855, where it was noted they had been "remanded so frequently" that:

> They were discharged, and sent to gaol; there to be well fed and well clothed until opportunity offered of forwarding them to Port Curtis; from thence they are to be sent to the island from whence they were taken (Anon, 1855f, p. 5).

We cannot know what the Percy Islanders thought of their appearance in Sydney, but given the starkness of the Water Police Court, we can assume they would have found the experience alien and daunting (Figure 4).

The Percy Islanders were not sent to Brisbane and hanged (contra CHAH, 2017). Limited archival documentation indicates that at least one child died in Sydney, and others were refusing food and becoming sick. The survivors were taken by the steamer *William Miskin* to Gladstone (Comben, 2017, p. 73). In a single newspaper reference post-dating the appearance of the Percy Islanders in Sydney by 40 years, it is noted:

> On the arrival of the vessel at Gladstone, the aborigines being apparently uncertain of their fate, jumped overboard during the night and made their escape. They were, however, destined to meet a worse fate. Falling in with a number of other blacks in the vicinity of Mount Larcombe, they were promptly murdered ("Variorum", 1898, pp. 17–22).

The events that occurred on the Percy Isles were widely reported in newspapers across Australia. A poem was written in honour of Strange (see above title of this paper), and for some time after, people recalled the events that occurred on the Percy Isles. For example, F. T. Huckell on the Australian Exploring Expedition to North Queensland in 1856 wrote: "… we passed close to Percy Island, where Mr. Strange

and some of his party were murdered" (Anon, 1856, p. 4).

In sum, the attack on the *Vision* was the first known lethal attack on Europeans on islands of the central Queensland coast. Later, Walter Hill indicated that access to water triggered the conflict, and this was confirmed by Dalaipi. When Frederick Strange was speared, he was able to remove the spear and shoot one of the islanders. This action subsequently triggered the death of Strange, Shinks, Spurling and Gittings. No further mention is made of Vann (able seaman) or Gray (ordinary seaman). Coote (2014, p. 84) suggests the deaths were "a judicial spearing gone wrong", but what this means exactly is unclear. Strange had previous experience in collecting around Bribie Island and had a conflict with Dundalli, but the nature of this conflict is unknown and it is impossible to tell what impact this might have had on Strange's attitude to Aboriginal people on the Percy Isles (Connors, 2015, p. 154).

When the Percy Islanders appeared before the Water Police Court in Sydney, they were portrayed as "savages", but somewhat ambiguously as harmless, perhaps childlike, and there is a prurient interest in their demeanour and nakedness. The events that occurred on the Percy Isles created great interest throughout the colony and were widely reported. Significantly, the theme of the poem by "G.F.A." in *The Sydney Morning Herald* of Saturday 4 April 1855 highlighted the thinking of many colonists of the day that events on the Percy Isles were a battle between the "heroic men of science" and the "untutored native savage". In the colonial process, the obtaining of scientific knowledge added to colonial power. Exploration and scientific surveys were viewed as patriotic and heroic due to the dangers of a hostile and remote environment, though the explorers and naturalists themselves often came to rely on Aboriginal populations for guidance through the country (Noonan, 2016; see also Coote, 2014; Reynolds, 1980; Meston, 1895, p. 128; 1921, p. 12). Passage through unfamiliar societies and polities was made less fraught and less subject to failure as a result of assistance from Indigenous agents (Kennedy, 2013, p. 2), but sadly their voices are rarely heard or have been frequently overlooked.

In a biography of Frederick Strange, it was claimed that the Percy Islanders were tried in Sydney, "found

FIGURE 4: Water Police Court, Phillip Street, Sydney 1870. Courtesy State Library of New South Wales.

guilty and the 6 aborigines were returned to Brisbane, Moreton Bay NSW (Qld) where they were hanged" (CHAH, 2017). The author claims the original source for this information as Meston. However, there is no evidence for the hangings occurring in Brisbane in Meston's *Geographic History of Queensland*, nor in a briefer account by Meston in *The Sydney Morning Herald* (Meston, 1895, 1921). The Percy Islanders were not hanged in Brisbane. In the two decades prior to the establishment of Queensland, there were 10 legal executions in Brisbane which did not include individuals from the Percy Isles (Connors, 1992, pp. 48–57). The account by "Variorum" in *The Capricornian* of 2 April 1898 suggests they jumped overboard at Gladstone and were subsequently murdered by Aboriginal people from Mount Larcombe. However, no other records could be located to support this claim and it is possible, given the nature of events in the area, that something more sinister may have occurred. Conflict was beginning to increase throughout the area, and it is possible that white retribution was visited on the prisoners (Comben, 2017, p. 74).

## OTHER COASTAL CONTACTS AND CONFLICTS ALONG THE CENTRAL QUEENSLAND COAST

Following the attack on the *Vision* in 1854, a number of other contacts occurred on islands of the central Queensland coast. Records relating to these events are less complete and often contradictory. Nevertheless, they do reveal a growing resistance by Aboriginal people along the coast and some of the reasons that sparked the resistance.

The first event involved the *Santa Barbara*, which sailed north in September 1859 under the command of Captain Henry Sinclair, with passengers Ben Poole and James Gordon who wrote an account of what transpired (Breslin, 1992, p. 49; Gordon, 1934?; Kenna, 1921, p. 11). On 18 September they reached Middle Percy Island where "The captain set fire to the grass, and in the evening there was a splendid sight, the whole island being in a blaze." On the 22nd and 23rd they went ashore and shot black-and-white cockatoos. No mention is made of Aboriginal inhabitants. On 13 October they reached Gloucester Island and had friendly contact with the islanders. However, on 14 October a canoe came out from the island and "The captain … wished to shoot the blacks while in the water, but I [Gordon] persuaded him not to do so." On 16 October they sailed back to the Cumberland Islands in search of water. The captain and Gordon went ashore to fell a pine to make a new bowsprit and were meet by three islanders. They were initially friendly, and the captain went off with them. However, later he was seen running down a hill pursued by the islanders hurling stones after him. Poole and Gordon fired on the islanders, who bolted into the scrub. The captain was bleeding and "much hurt". Gordon noted: "We all felt indignant at these treacherous scoundrels, and would have liked to shoot every one of them, but they had bolted into the scrub" (Gordon, 1934?, p. 5). Sinclair later died in Cleveland Bay on 17 March. There is no evidence to support the claim by Haebich that "an unknown number of Aboriginal men were shot and possibly killed" on this occasion (Haebich, 2008). Breslin (1992, p. 43) notes that in 1860 Dalrymple and Smith of the *Spitfire* also distorted the level of hostility in the area, based on the attack on the *Santa Barbara*.

In 1860, four people from the *Caroline* were allegedly killed at Homestead Bay on St Bees Island. In this case: "In a short space of time they had been pinned and butchered savagely, under the horrified gaze of their shipmates, back on board" (Winsor, 1982, p. 12). These events cannot be verified in any other source and are not mentioned by Ørsted-Jensen (2011). It is also alleged that the *Dundas* sheltered in the bay six months later and that Aboriginal people boarded her at night and killed all but the captain, who managed to get the ketch back to Bowen (McIvor, 1878). The attacks on the *Dundas* and *Caroline* lack verification, and unless more details come to light, they remain unsubstantiated (Blackwood, 1997, pp. 22–23).

The ketch *Ellida* left Bowen on 25 August 1861. On board were master Thomas McEwen, seamen Nicholas Millar and Patrick Savage, and passengers Henry Irving, Lowe and Byerley. On 27 August they were in the lee of an island in the Shaw Group when a canoe came out from one of the islands; its Aboriginal crew were encouraged to come on board and were given fishhooks and biscuits. They then returned to shore where there was a considerable number of their group. They returned with three more canoes, each carrying two people bringing presents of fish and spearheads; they were very friendly and unarmed. Millar got into one of their canoes, landed on the island and cut a spar for the squaresail. The Aboriginal people brought him back with a supply of firewood for the boat. He then proposed to Irving to go ashore to gather oysters, and he and Savage went ashore in the canoes. On landing, they were received in a friendly manner. However, later those Aboriginal people with Irving tried to get his carbine away from him. In the following attack, Irving and Millar were killed and their bodies were

seen on shore, where the natives were "mangling and ill-using them". The *Ellida* retreated to Whitsunday Island, where there was a camp of Native Police. It was proposed to try to rescue the bodies, but the idea was abandoned in view of the large numbers of Aboriginal people (Anon, 1861a, p. 2). As soon as information was received at Bowen of the murder of Irving and Millar, the Commissioner of Lands, George Dalrymple, proceeded with the *Santa Barbara* and his own boat to the islands. Accompanied by Lieutenant Williams and a party of Native Police, they "made descents on the savages encamped there". But the Aboriginal people managed to escape to inaccessible parts of the island. The remains of Irving and Millar were located and interred, and "the blacks' camp was spoiled, and their canoes destroyed or taken away" (Anon, 1861b, p. 2). Loos reports the 1861 death of Irving and Millar as the first on the sea frontier, but this overlooks the 1854 events on the Percy Isles (Loos, 1982, pp. 124, 194).

On 30 May 1862, the cutter *Presto*, commanded by Captain William Hart, anchored between Shoal Point and Cape Hillsborough where he had sighted some Aboriginal people. Two passengers, Roberts and Sommerville, accompanied the captain ashore. Hart was unarmed for fear of causing alarm. He gave bread and tobacco to the four Aboriginal people whom they met, and made signs that they were looking for a cattle station. The four Aboriginal people made signs for Hart and his men to follow them. However, Roberts insisted on going alone. Another 12 Aboriginal people then arrived with nullah nullahs. Two more crew from the *Presto* landed and by displaying guns managed to subdue the Aboriginal people's hostile approach. Hart and the crew searched the nearby scrub but found no sign of Roberts. The next morning they sailed for Rockhampton to report the disappearance of Roberts to John Jardine, the local Police Magistrate (Kerr, 1980, p. 37; Loos, 1982, p. 194; Queensland State Archives, 1862). This event is not mentioned by Ørsted-Jensen (2011).

The schooner *Nightingale* left Sydney on 21 January 1864 for Bowen. On 8 February 1864 it became stuck in a cyclone and beached on Long Island. The crew made a boat out of planks and on 22 February headed north. They suffered many hardships and were attacked by Aboriginal people from Lindeman Island but were picked up by the *Three Friends* of Bowen. It is claimed that the captain of the *Nightingale*, Quinn, later died at Bowen (Anon, 1864, p. 4). Confusion surrounds this event, since Breslin (1992, p. 78) claims that the crew of the *Nightingale* fell in with a group of Aboriginal people who "harboured them", and Ørsted-Jensen (2011, Appendix A) notes that the Master (unnamed) of the *Nightingale* was murdered at the mouth of the Burdekin River.

The *Louisa Maria* beached on Whitsunday Island on 16 August 1878 to clean her bottom. On board were the captain, McIvor; John Johnson of Brisbane; John Morrison, the cook; and Andrew Walker, a carpenter. Relations with the island Aborigines were initially friendly, but subsequently Morrison was thrown overboard and McIvor was speared. Aboriginal people were seen passing the sails of the *Louisa Maria* into their canoes and, soon after, the vessel was seen burning. Morrison was not located, and the survivors headed first for Bowen but later for Mackay. They were picked up by the *Riser* and went back to the island, and at daylight found that only the topmast and mainmast of the *Louisa Maria* survived. Aboriginal people were seen walking along the beach, and McIvor and three men went ashore. The Aboriginal people ran behind rocks and into the scrub, and began throwing stones and making fun of the men. Three shots were fired at them but without effect. Seeing nothing further could be done, they left for Bowen (Anon, 1878a, p. 3; Loos, 1982, p. 222; McIvor, 1878, p. 2; Ørsted-Jensen, 2011, p. 238). The Bowen correspondent of *The Brisbane Courier* noted:

> It is said that the authorities will send a body of black troopers to the island to disperse the savages in the orthodox Queensland native police fashion. Most of the blacks engaged in this diabolical act can be identified. If caught, it might have a wholesome effect to hang them, and compel as many natives as could be brought together to look on (Anon, 1878b, p. 5).

George Nowlan led a detachment of Native Police to the Whitsunday Islands, where the troopers spent a week executing "reprisals", and it is stated that the islanders were "permanently 'dispersed', and that they will trouble calling vessels no more" (Anon, 1878c, p. 6). The local historian Blackwood notes that despite diligent searching at the State Archives, an official report on the matter could not be found (Blackwood, 1997, p. 23). Nevertheless, Richards concludes from what is known of frontier euphemisms like 'permanent dispersal', it is reasonable to suggest the killing of many innocent people took place (Richards, 2008, p. 147). This is supported by Coppinger's account of his visit to the lighthouse on Dent Island in 1881. He was told by the lighthouse people that following

the attack, the Queensland Government had made an example of the attackers by letting loose a party of black police, "who, with their rifles, had made fearful havoc among the comparatively unarmed natives" (Coppinger, 1883, pp. 185–186).

Ørsted-Jensen reports that a European (unnamed) was killed by Aboriginal people in the Cumberland Islands in 1880, and also the death of Henry Greenlaw and the mate, George Jones, of the *Beryl* near Barrow Point at Knight Island in 1893 (Ørsted-Jensen, 2011, pp. 239, 248). McNiven and colleagues refer to a police inspector and black trackers "dispersing" Aboriginal people on Collins Island in Shoalwater Bay in the early 1870s in retribution for the murder of a local Chinese *beche-de-mer* operator (McNiven et al., 2014).

In sum, it is claimed that the Aboriginal people of the Whitsunday Island Group had an "evil reputation", but this appears to be inflated. For example, there is no evidence for cannibalism as implied by *The Argus*, and cannibalism was rare if non-existent, but exaggerated in order to subdue Aboriginal people (Behrendt, 2016, Chapter 6). From the time of Cook's passage through the islands in 1770, until 1861, relations were largely amicable (Barker, 2004, p. 26). Significant attacks on shipping began after 1861 with the establishment of Bowen. Breslin notes that in establishing Bowen, George Dalrymple had no intentions of establishing good relationships with Aboriginal people (Breslin, 1992, p. 56). Attacks on European ships after the establishment of Bowen brought harsh retaliation from the Native Police (Coppinger, 1883, pp. 183–193; Rhodes, 1937, p. 100), though substantive records are difficult to locate (Blackwood, 1997, pp. 22–23).

Following the attack on the *Vision* at Percy Island in 1854 when four European men were killed, the *Santa Barbara* was attacked in 1859, resulting in the death of Captain Sinclair. There are then unsubstantiated accounts for the deaths of four European men: two from the *Ellida* in 1861 at Lindeman Island, one that may also have occurred on the *Nightingale* in 1864, and one that occurred on the *Louisa Maria* in 1878. Mr Roberts from the *Presto* disappeared in 1862. Therefore, between 1854 and 1878 there were no more than 11 (and maybe as few as six) European deaths resulting from conflicts on the islands. The number of Aboriginal deaths is largely unknown but was likely high.

## DISCUSSION AND CONCLUSION

From the late 1960s, Australian historians began to investigate the impact of colonisation and dispossession on Indigenous Australians and on Indigenous resistance to the impacts (Reynolds, 1982; Reynolds & Loos, 1976). Interpretations led to the so-called 'Black Armband' or 'White Blindfold' versions of the past and ultimately to the so-called 'history wars' (Attwood, 2005; Evans, 2010; Macintyre & Clark, 2003). It is now recognised that a more nuanced approach is required, where complexity and contradiction are critical (Clark, 2002).

To suggest that British colonies in Australia were civilised societies governed by morality and laws that forbade the killing of the innocent, as proposed by Windschuttle, is seriously flawed (Windschuttle, 2002). Apart from direct killing, the colonists caused resource disturbance and depletion, and introduced diseases which took a heavy toll on Aboriginal populations across Australia (Campbell, 2002). Equally, to idealise the Aboriginal past as a time of peace and harmony does no justice to the evidence and no service to historical truth (Behrendt, 2016, Chapter 7; Rowland, 2004b; Sutton, 2009). But the impact of Europeans on Aboriginal people was disproportionally higher on all measures. While Reynolds and Loos, for example, could account for 800 to 850 deaths of Europeans in the 50 years it took for the colonial settlement of Queensland, they estimate that retaliation by settlers was in the order of at least ten to one. (Reynolds & Loos, 1976, p. 214). Ørsted-Jensen (2011, Appendix A, p. 251) has estimated that perhaps 121 Europeans met their death at the hands of Aboriginal people on the east coast and Gulf coast of Queensland (and another 186 in Torres Strait). From the initial small-scale skirmishes on the coast, there are now revised estimates of 25,000–30,000 Aboriginal and 2500–3000 European deaths (Reynolds, 2013, p. 245), and more recent estimates of an Aboriginal death toll in excess of 60,000 for Queensland (Evans & Ørsted-Jensen, 2014). Prior to permanent European settlement on the mainland, the number of deaths on the islands of central Queensland were relatively small, though suffering on both sides of the frontier was significant.

European and Aboriginal people met in such a wide variety of circumstances that it may be difficult to reduce the diversity of contacts to simple generalised patterns of behaviour (Reynolds, 1982, p. 20). But some general patterns can be recognised. Mulvaney, for example, notes that every instance of contact took place on Aboriginal land, but that few of the newcomers acknowledged this reality (Mulvaney, 1989, p. 1). But first encounters cannot be seen purely in territorial terms. They may instead be seen as encounters with relatives who had gone to the spirit world and

returned. These were a malevolent and "tricky" group to flee from or attack (Sutton, 2008, p. 54). The rules governing relationships in Aboriginal society were also highly structured, placing strict obligations both on the hosts and the visitors. A mutual ignorance of behavioural rules and individual roles produced many conflicts. Europeans, for example, were unaware of the Aboriginal concept of 'balanced reciprocity' and pressed goods on Aboriginal people without understanding what this meant (Breslin, 1992, p. 29). Most Europeans did not seem to realise they also breached Aboriginal law by fishing and gathering in Aboriginal territory without permission (Breslin, 1992, p. 32).

Elkin (1951) has argued that, from 1788, a general picture from across Australia was of Aboriginal people as shy and harmless. They did not rebuff newcomers, who were seen to be temporary sojourners. However, when it became obvious that the newcomers were to remain and that their numbers were increasing, clashes over resources became commonplace and Aboriginal people began to offer overt and determined resistance. In most areas prior to permanent European settlement, Aboriginal people were given an accurate preview through their own networks of what European civilisation had to offer, which included disruption, denigration and disrespect (Breslin, 1992, p. 29; Reynolds, 1982, p. 15).

The sea may be perceived as an unwelcome wilderness, while the land is an area of safety; or alternatively, it might be seen as entirely familiar and unthreatening (Mack, 2011, p. 74). It is likely that Aboriginal people of the Queensland coast found the islands and the sea largely unthreatening, while the early explorers may have been less confident of their surroundings. Europeans who landed from ships were usually in quite small parties. They could obtain water and other resources. Aboriginal people could gain access to the white man's goods without the disadvantages of permanent European settlement (Reynolds, 1982, pp. 174–175). But this should not obscure the significance of Aboriginal resistance to seafaring Europeans (Reynolds, 1982, pp. 181–182). Reynolds notes that shipping through the Whitsunday passage was particularly vulnerable to attacks although, as I have shown, evidence for this prior to the establishment of Bowen in 1861 has been exaggerated. Nevertheless, the *beche-de-mer* industry is thought to have exploited coastal Aboriginal people as early as the 1840s, and by the 1870s the kidnapping of Aboriginal people along the coast and adjacent islands was common practice (Donovan, 2002, p. 81; Loos, 1982, pp. 122–123, 141). While most islands visited by early explorers on the central Queensland coast revealed evidence of Aboriginal presence, actual sightings were fewer and large gatherings not common. Prior to about 1859, the intermittent contact between explorers, Royal Navy hydrographers, traders, castaways and Aboriginal Australians was one devoid of any desire to possess and subdue Aboriginal lands. The relationship was therefore an essentially friendly one, and the Aboriginal inhabitants may have generally accepted brief visitations by Europeans who then subsequently moved on (Breslin, 1992, pp. 1, 15).

From 1859 on, however, the white invasion began (Breslin, 1992, p. 1). Gladstone was established with the arrival of a contingent of Native Police in 1854 (Loos, 1993). Dalrymple began establishing the first permanent settlement at Bowen in April 1861, and mainland conflict commenced on a much greater scale (McDonald, 1988, p. 16). Europeans were now taking up large tracts of land for pastoral uses and stocking them with cattle and sheep, commandeering waterholes and preventing clans from using them (Bottoms, 2013, p. 18). It has long been recognised that frontier conflict was a form of warfare (Flanagan, 1888; Reynolds, 2013, p. 130), and Reynolds has recently made it abundantly clear this was the case in Queensland. For many years the Queensland Government funded and administered a force that shot Aboriginal people in large numbers (Reynolds, 2013, p. 153).

As McNiven (2001) has pointed out, research on maritime frontiers has been limited. But they were dynamic and changed in nature through time. They have the potential to vary enormously in detail. A diversity of Aboriginal and Torres Strait Islander groups met with a diversity of outsiders from varied cultural backgrounds with different outlooks and intentions (McNiven, 2001, p. 178). It is impossible to generalise what the range of European views might have been, but the sad, chillingly brutal honesty and fatalistic views of "Rusticus" were probably all too common:

> As to their being hostile, we need not be surprised, as they consider us invaders, which, in fact, we are; but we are placed in this predicament, – we must either retire from the place and leave a smiling country in the hands of a few cannibals, or we must protect our lives in such a manner as to convince the savage that he is powerless to cope with the white man's arms, and teach him that his only hope of safety lies in submission. The former alternative I don't think any sane man would think of adopting (Anon, 1861, p. 2).

There was arguably an official 'conspiracy of silence' in respect to violence on the frontier, but "there was also a considerable stream of minority reportage, in the colonial press, in official documentation, in private or public letters, in dairies, pioneer memories and confessionals" of what was a bloody struggle (Evans in Bottoms, 2013, pp. xvii–xiv). Nowhere is this more clearly demonstrated than in Queensland (e.g. Breslin, 1992; Donovan, 2002; Evans, 2010; Ørsted-Jensen, 2011; Reynolds, 2013; Richards, 2008). Barker (2007) has argued that the nature of Australian frontier conflict was such that there is little probability of massacre events being manifested in the archaeological record, but Litster & Wallis (2011) indicate that violence was ubiquitous on the Australian frontier and offer a range of evidence that might be indicative of such sites. Thus, both the historical and archaeological record should continue to provide evidence of contact and conflict.

The evidence of conflict on the Percy Isles and other islands of the central Queensland coast again draws attention to the debate over numbers and terminology. While numbers and terminology matter historically, we should not lose sight of the complex range of suffering experienced by both Aboriginal people and Europeans on both sides of the frontier(s) (Rowland, 2004a).

In an otherwise insightful account of Australian exploration, Kennedy (2013, p. 91) notes:

> Australian explorers also ran the risk of attack by indigenous peoples, and a few of them were killed. But most Aborigines either fled at first sight of explorers or found them keen sources of interest. Some sought trade and offered assistance, while those who did seek to harm these strange interlopers used such simple weapons that the wounds they inflicted rarely proved fatal. More members of expeditions probably were injured or killed as a result of the accidental discharge of their guns, falls from horse, and other mundane misfortunes than because of the murderous designs of hostile natives.

Kennedy is wrong on most counts. Aboriginal people were not murderous by intent. They were not "untutored savages", nor were they "noble savages" (Rowland, 2004b). They were people who defended themselves, their families, communities and cultures. They rarely fled but, for a host of reasons, defended themselves and their territories. Europeans were killed by Aboriginal people, but far greater numbers of Aboriginal people were killed in return. Human suffering occurred on both sides. Stories of frontier contact are available from an abundance of sources (Bottoms, 2013, p. 207; Reynolds, 1982, p. 201; 2013, p.31). Detailed presentation of local and regional conflicts as undertaken here and elsewhere (Rowland, 2004a) tell powerful stories of contact and conflict, otherwise often overwhelmed by collective statistics and broad generalisations. Sadly, however, Aboriginal voices all too often remain silent.

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# ESSENTIALISTIC PLURALISM: THE THEORY OF SPATIO-TEMPORAL POSITIONING OF SPECIES USING INTEGRATED TAXONOMY

Maxwell, S. J.[1], Congdon, B. C.[1,2] & Rymer, T. L.[1,2]

The resurrection of essentialist arguments, in the context of the modern evolutionary synthesis, highlights the need for a break from historical definitions of 'kind' and 'essence' in order to bring a new paradigm in which these terms are used to conceptualise and understand evolutionary processes. The definition of 'essence' is herein divided into two distinct parts, namely the structural essence, which is mutable and has an evolutionary context; and the character essence, which is the immutable spatio-temporal expression of the structural essence of an individual. In contrast, the 'kind' is herein redefined as a region within a wider phylogenetically constrained organism state that reflects a conflux of character essences that form an immutable semaphoront. This organism state enables the hypothetical delineation of spatio-temporally immutable forms, called species, which are drawn from an evolutionary continuum. These revised definitions and the taxonomic clades derived from them determine the species that are used in the construction of phylogenies that reflect true historical and evolutionary relationships between organisms. The use of integrated taxonomy allows taxonomists to choose the appropriate concept enabling the evolutionary significance of the organism to be explained. This refocuses the argument from the concept back to the criteria, but often at the cost of causal explanation or conceptional explicitness. While integrated taxonomy allows the taxonomist the freedom to delineate species outside of any rigid conceptual framework, we seek to apply to this freedom a limit to the understanding of the evolutionary potential of an organism through the framing of that organism in a fixed spatio-temporal point. We call this confined potential the 'essence matrix', and it is these boundaries of this matrix that define the evolutionary potential of past and future forms, as well as define and restrict the field of morphospace upon which convergence and reticulation of taxa can occur. We name this limitation on evolutionary potential, the essentialist arguments used to construct it, and the integrated taxonomic approach to criteria selection, 'essentialistic pluralism'. Finally, we will examine the complexity of species demarcation, noting the continuing failure for explicitness in conceptual application even if criteria are obvious.

Keywords: kind, essence, essentialism, evolution, species taxonomy

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## INTRODUCTION

The natural world is classically ordered according to hierarchical relationships that are constructed in a manner that does not reflect modern evolutionary principles and the new biological essentialist paradigm. The historical pursuit of inferring the natural relationships between organisms is primarily a by-product of human intellectual inquisitiveness and reflects a pseudo-theological search for understanding the natural order of life, a quest that has challenged philosophers and those interested in the sciences before the Common Era (Henry, 2011; Lewis, 1963). As scientific understanding and shifts in theological influence have changed over time, so too have the processes and doctrines underpinning methodical approaches among those disciplines concerned with finding an optimal system of nomenclature similarly changed (Moritz, 2013).

The shift from theocratic creationism towards an evolutionary necessity in taxonomy has challenged the hierarchical orthodoxy conceptualised and instituted by Linné (1735, 1758). This challenge has led to conflict and a rigorous defence of systems of nomenclature based on personal ideology rather than theoretical optimisation (Brummitt, 2002; Cantino et al., 1999). Irrespective of the ideological stance taken, any system

of nomenclature needs to impart a sense of ontology, or reality, as well as to possess an inherent epistemology that enables a delineation of how derived taxonomic conceptional entities reflect the taxonomic needs of the classifier (Szalay & Bock, 1991). Consequently, taxonomists are drawn towards particular taxonomic schools of thought based on their personal understanding of evolutionary theory, taxonomical needs and predisposition towards an ideological stance on a particular taxonomic or species concept (Cracraft, 1987).

In order to re-engage the wider scientific community in the species debate, there needs to be an acceptance that the term 'species' has fundamentally differing meanings (Schlick-Steiner et al., 2019). The use of integrated taxonomy, with its unrestricted approach to conceptualisation of what is a species, allows the taxonomist the freedom to express a unique approach to exploring phylogeny without the shackles of rigid necessity to declare adherence to a single species concept (Yeates et al., 2011; Pavan & Marrioig, 2016; Solari et al., 2019; Pardo-Diaz et al., 2019). The broader scientific community can be brought back to the species debate only when there is an acceptance that there is no correct or incorrect conceptuality in species definition, with all proposed species concepts theoretically having a usefulness (Schlick-Steiner et al., 2019). Many scientists have avoided species debates in evolutionary biology as a consequence of the semantics surrounding many of the current issues (Noor, 2002; Pante et al., 2015). Much of this avoidance can also be attributed to conceptual misunderstandings and ignorance of the theoretical basis for what actually constitutes a species. The broader scientific community can be brought back to the species debate only when there is an acceptance that because they are hypothetical there is no correct or incorrect conceptuality in species definition, with all proposed species concepts theoretically having usefulness (Hausdorf, 2011).

Species need to be conceptualised outside of taxonomic classificatory systems as they fall outside of systematic hierarchical arguments, being fundamentally hypothetical (Dubois, 2011). Although hypothetical in nature, a species hypothesis is represented by a set of real organisms. Thus, because species are real entities and not just intentional meanings derived by the taxonomist, they differ innately from higher classifications which are subjective in that there is no physical representation of the hypothetical rank (Ghiselin, 1974; Hull, 1976). This raises a point of contention: if species are real, why are many of the concepts that are used to define them based on unreal or non-causal criteria? This leads to a complexity in conceptual realisation and invariably to conceptual misunderstanding, a problem again absent in higher taxonomic arguments that have no physical reality (Stamos, 2003). There is a need for criteria to give a sense of a touchstone to the real.

One of the problems with engaging a taxonomist in the species conceptual debate is that they are often at a loss to explain their meaning of species, falling into the trap of conceptual adherence and associated rhetoric and overlooking the hypothetical nature of the reference point in nature they seek to demarcate. Such rigidity to a conceptual belief invariably ends with the taxonomist at a loss when faced with contra-arguments (Hey, 2001). This adherence to a conceptual framework also loses sight of the primary mission of the taxonomist, which is, according to Mayden (1999, p. 115), "to discover, describe, and classify biological diversity, regardless of how much there may really be out there". It is also irrational for a taxonomist to bind him/herself to any concept due to its convenience in application or acceptance by the wider collective scientific community (Nadachowski, 1993). Further, the long-term species debate has failed to enunciate the significance of the nuances of the species concept applied by the practising biologist. The application of species concepts is used to make critical decisions that affect universal biodiversity and macroecological assessments, as well as provide the support for evolutionary understanding in fields well apart from the narrow frame of their activities (Hey et al., 2003; Tan et al., 2008; Naomi, 2011; Frankham, et al. 2012). This has never been more relevant than in contemporary taxonomic practice, with the rise of conservation-orientated systematic arguments which seek to limit the ability of the taxonomist to undertake wide-ranging revisions, with such revisions seen as a threat to global diversity (Garnett & Christidis, 2017; Thomson et al., 2018; Gangloff, 2019).

Taxonomic descriptions of new species are often fundamentally flawed as there is generally no explicit statement of the species concept used to delineate the taxon (Tan et al., 2008). This lack of conceptual explicitness leads invariably to three primary errors in the systematic demarcation of species:

1) Type I errors occur when there has been an overestimation of the number of species within a particular organism complex;
2) Type II errors occur when the number of species in the organism complex has been underestimated; and

3) Type III errors occur when there has been a misrepresentation of the systematic relationships between the organisms within the complex (Adams, 1998). This has serious implications for understanding evolutionary history, where "irrational" species could lead to a misrepresentation of the evolutionary progression of a clade (Adams, 1998), or in the conservation of endangered organisms (Garnett & Christidis, 2017).

When determining a species, a taxonomist has an obligation to nominate the species conceptual approach being followed, to ensure a clear understanding of the criteria that are necessary and sufficient to determine the population (Hausdorf, 2011). The need for explicitness in criteria brings the theoretical problem of species recognition back within the scope of the rules of nomenclature that govern the application of names (Knapp, 2008). In addition, the taxonomist has an obligation to inform on the actual process of speciation that has taken place, giving insight into the ontology and causation of organismic differentiation (Miller, 2001; Losos & Glor, 2003). The use of integrated taxonomy enables the taxonomist the freedom to choose species criteria that are most appropriate for the set of organisms, irrespective of definitions that may have been applied to their sister taxa. However, this freedom in descriptive modality needs to be coupled with conception explicitness, that is, not just state the method used to discriminate a taxon, but answer the causal question as well.

In this paper, we redefine 'biological essentialism' through the differentiation of the two concepts of 'kind' and 'essence' that have become erroneously synonymised in modern evolutionary theory. In addition, we will demonstrate that a 'kind' is a part of an organism state, which is a fixed, discrete entity within a spatio-temporal framework that is defined by essences. The edges of the organism state represent the phylogenetically constrained boundaries of an organism at a particular point in time. Further, we will consider the pluralist approach to understanding what constitutes an 'essence', that is, the integrative taxonomic freedom to determine the criteria or species delimitation, and specifically describe two discrete forms of essence, namely the 'character essence' (Box 1), which is a spatio-temporally fixed character, and the 'structural essence' (Box 1), which is mutable and has an evolutionary context, a distinction that has yet to be fully explored within the literature. We present the 'essence matrix', which confines the organism state to a discrete boundary of evolutionary potential for an organism to reticulate and evolve within through time. Further, this paper will demonstrate that essentialistic pluralism is a standard for universality and addresses the need of species demarcation at its core: what is the intended meaning imparted by naming an organism and not just the criteria used to describe and differentiate it?

## ESSENTIALIST TAXONOMY

Essentialism has a valuable role to play in providing an understanding of evolutionary processes as it explains the evolution of both the intrinsic and extrinsic natures of taxa (Walsh, 2006). Understanding the dualistic nature of taxa requires an acceptance of the evolutionary reality that organisms evolve subordinate monophyletic groups that have an ancestry determined by the linking of real organism states (Box 1) and not some evolutionary ideology (Brundin, 1972). Organism states are, in turn, defined by 'kinds' (Box 1), which are created by the congruence of 'structural essences' (Box 1).

BOX 1. Glossary of new and revised significant taxonomic terms.

*Organism state*: The phylogenetically constrained boundary of all potentially expressed essences that a biological population (considered a species) exhibits at a static point in its spatio-temporal evolution, that is, a holomorph.

*Kind*: A region within an organism state that represents a conflux of an organism's structural essences, and reflects the nature of an organism at a point in its evolutionary progression; an immutable semaphoront.

*Structural essence*: An evolutionary trait that may represent a phenotypically plastic form, or an ecological boundary, which defines an intrinsic or extrinsic aspect of the organism.

*Character essence*: The immutable attribute of an individual that reflect a spatio-temporal expression of structural essences.

*Essence matrix*: The entire collection of structural essences that unifies the ancestral and descendant taxa and is used to define the higher clade from which an organism state has evolved, and bounds that organism's potential for evolutionary divergnce in form into the future.

'Kind' and 'essence' have often been used interchangeably although they are different concepts. Consequently, they have been maligned in the arguments against immutability that have been used to support the drive towards neo-Darwinism and the modern evolutionary synthesis (Mayr, 1987; Amundson, 1998; Okasha, 2002). There has been considerable debate on the nature of what actually constitutes an 'essence'. We make six observations. First, historically, to taxonomists such as Linné, the term essence simply meant that which is taxonomically useful (Winsor, 2006). Second, many contemporary essentialist arguments are pseudo-Aristotelian, based on either shared salient morphology, or innate intrinsic properties that have explicit and rigid taxonomic meaning (Wallace, 2002; Oderberg, 2007). Third, the essence of an organism has also been linked to its genotype, which is then expressed in the observable morphological, physiological or behavioural characters it displays (Kitts & Kitts, 1979). Fourth, the genotypical approach has been further refined into the extended phenetical approach, where the definition of essence includes ancestry and relational biology (Walsh, 2006; Elder, 2008). Fifth, the more minimalist approach to defining the essence, based on a character trait, is outside historical necessity and is not intrinsic to the definition of an individual (Dumsday, 2012). Finally, in contrast, the phylogenetic approach seeks to shift the focus of essentialism from a categorical basis to a more historical one, thus enabling the essence to be used in evolutionary biology through the incorporation of intrinsic with extrinsic, or relational essences as part of a wider holistic view of the organism (Devitt, 2010; Dumsday, 2012). Irrespective of the approach taken to defining the essence, one of the failings of these theories is the inability to differentiate between two distinctive essence forms, namely the structural and character essences.

The structural essences of an organism state arise from the collective essence matrix, which defines the morpho-space of inclusivity of the higher taxonomy to which the organism, in all possible phenotypically plastic forms and ecological boundaries, belongs. This organism state can be viewed simply as the boundary of a species' variability at an exact point in space and time; that is, a species is a fixed cross-section of a continuum chosen by the taxonomist to give a reference point to advance an explanation of the observable natural world. In contrast, the character essences are the immutable attributes of an individual and the spatio-temporal expression of the structural essences at the point at which the species is circumscribed. Importantly, it is the character essences of a taxon that are used to provide the restricted definition of the kind within the broader organism state and are used to formulate the diagnosis of a species.

In the current essentialist debate, the concept of a 'kind' refers to an immutable form and is not linked to a particular end point in the hierarchical tree typology. Therefore, it is theoretically incorrect to refer to species in the classical sense in terms of discrete classes of natural kinds with an implicit immutability. Rather, species should be viewed as distinct representatives along a continuum, thus being evolutionarily plastic, rather than temporally variable. Kinds need to be viewed in terms of a convergence of structural essence axes within the organism matrix that enables the discernment of a collective type with an explicit taxonomic definition, albeit at the arbitrary judgement of the taxonomist (Forey, 2002). In this context, kinds represent the collection of units of change within an organism state that results from the subjective assessment of the unbroken chain of divergence (Dobzhansky, 1935). The kind forms a statement of evolutionary position chosen by the taxonomist to reflect a more inclusive organism state comprised of evolving structural essences.

Mayr (1987) rejected kinds, arguing that natural kinds were sterile, and consequently, this terminology should be restricted to inanimate objects, such as metals. However, this is an incorrect assumption based on an innate restrictiveness and lack of historicity that has been applied to the classical definition of a kind. Further, Mayr's approach is a rejection of the premise that species are capable of evolving, which is not upheld under the revised definition.

## HISTORICAL PERCEPTIONS OF SPECIES

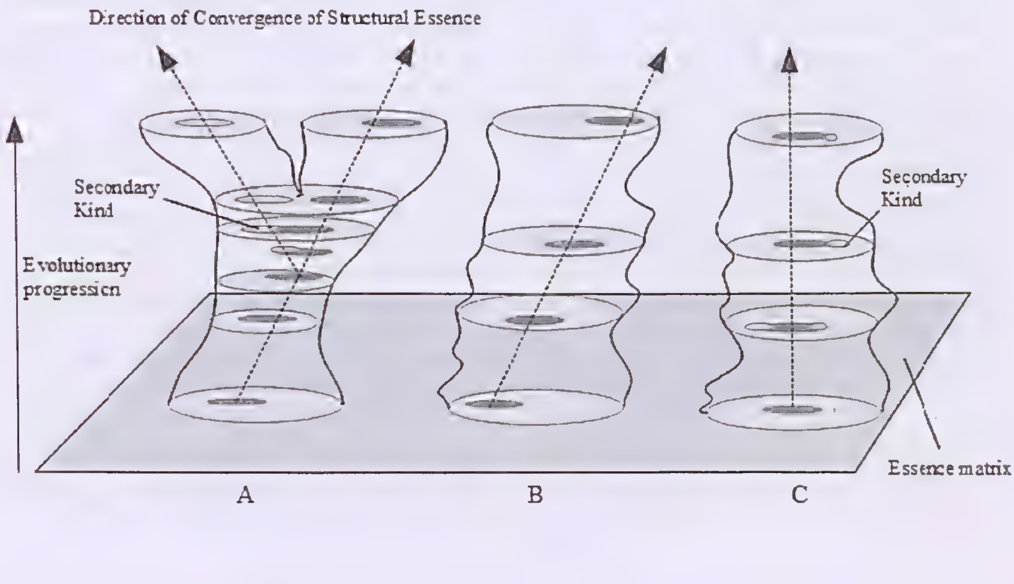
Darwin (1859) argued that species are arbitrary constructs of convenience selected from a fluctuating evolutionary pond of forms. This argument mirrors the belief that species are not discrete, but rather become indistinguishable within a merging metapopulation, where essences reticulate between individuals as populations (Lamarck, 1801). This idea was extended in the adaptive field theories of Wright (1932) and Dobzhansky (1951) in which discernment of taxa occurs at topological peaks of adaptational success. The valleys between the combination of genes indicate a point at which discrete organisms can be delineated from one another (Dobzhansky, 1951). Species, therefore, are hypothetically derived

with the choice of demarcation, a decision made by the taxonomist.

The determination of a method to demarcate species has been a complex argument that has lasted centuries. Species need to be contextualised as a direct and discernible product of evolution constructed on a set of unifying essences chosen by the taxonomist. This currently occurs under guides of a theoretical concept chosen by the taxonomist. It is worth noting that the word species *senso stricto* has two primary uses: it is used by taxonomists to delineate the forms within nature and create hypothetical hierarchies and, at the same time, it is used as a definition by the taxonomist to form a discernible immutable kind that acts as a hypothetical name-bearing reference point from which the process of evolution can be described (Mayr, 1987, 1996; Ereshefsky, 1992; Pleijel & Rouse, 2000). However, a species has a unique history and forms the more inclusive individual taxon with characteristics that are often not exhibited by the kind (Mishler & Donaghue, 1982; Nixon and Wheeler, 1990; Wiley, 1980). In contrast, higher taxa are multidimensional, existing within a spatio-temporal continuum in which the shared characteristics, or structural essences, are acting as axes that reflect their unique evolutionary direction (Andersson, 1990; Szalay & Bock, 1991). When these axes converge, there is a forming of a discrete kind that can be given a formal definition (Dupré, 1981). Further, it is the relationships and clustering of these organism states based on shared ancestry that form the basis for the definition of higher taxa.

The birth of a new species, or delineation of two taxa, occurs in two ways. First, via the process of heterochronic cladogenesis, where two distinctive convergences arise in the organism state and the cleavage of new identifiable species with new identified phylogenetic constraints is deemed appropriate by the taxonomist (Huxley, 1957; Gould, 1977; Aze et al., 2013). Second, via the process of anagenesis, where a particular set of essences consistently converge outside the parameters of the parental metapopulation, as defined by the kind, requiring a redefinition of the kind (Huxley, 1957; Aze et al., 2013). While the acceptance of stasiogenesis implies that there is no multiplication of species and evolutionary failure, it may also reflect internal reticulation of the kind that reflects a convergence about a conflux of evolutionary optimisation (Huxley, 1957; Crusafont-Pairó & Truylos-Santonja, 1958; Figure 1). This reticulation has significant implications for phylogenetic reconstruction where only one gene has been utilised and the results may reflect only

FIGURE 1. The use of structural essences and the organism state to illustrate how the delineation of a kind can reflect modes of evolutionary phylogenesis: A) cladogenic evolution, in which there are two distinctive kinds created, each with individual phylogenetic constraints; B) anagenic evolution, where there is a shift in the structural essence convergence giving rise to distinctive changes in the kind within the relatively constant phytogenetic constraints; and C) stasiogenic evolution, in which there is no change in the kind, illustrating also that, while the phylogenetic constraints remain relatively stable, there may be reticulation.



gene evolution rather than the true state of the historical relationships between organisms. Evolution is more than the addition or subtraction of genetic material, but rather reflects an interaction of gene systems: the transitional valleys between gene clusterings represent taxic exploration of evolutionary possibilities rather than the initial stages of a genetic conflux giving rise to a new taxon (Dobzhansky, 1951).

Notwithstanding the mode of speciation, there is a necessary need for the generation of artificial temporal evolutionary stasigenesis for the delimitation of an organism state for the purposes of generating systematic understanding. This artificial stasiogenesis introduces an explicitness into the definition of species that then enables the production of real propositions on the historicity of the evolution of organisms. Taxa are explicitly defined in terms of kinds to avoid ambiguity and facilitate effective communication of the biological entity, reflecting the convergences of the axes even if these kinds are only representative of the wider, more-inclusive organism state (Dupré, 1981; Bryant, 1996). In point of fact, kinds represent nothing more than the adaptive peaks of an organism state.

Avise et al. (1987) highlight the complexity of gaining an understanding of the evolutionary significance and determining within an organism state when, from the extrapolation of a number of microevolutionary events, macroevolution is said to have occurred. Avise et al. (1987) saw macroevolutionary patterns as a substrate that is formed by the branches and twigs of intergenerational pedigrees within the complexity of phylogeny. One of the major theoretical standards for the delineation of a species from the myriad of branching possibilities is the simultaneous establishment of joint possession of structural essences, or synapomorphies, in each line (Bremer & Wanntorp, 1979). However, strict adherence to this method of differentiation has been found to be problematic in delineating when a novel structural essence, from the time of origin to fixation, gives rise to a new kind in a spatio-temporal organism state. This can be resolved by the defining of ancestry in terms of the absence of structural essences. However, the problem with this approach to the delineation of ancestor-descendant relationships lies in determining the temporal points of divergence, or when an adaptive peak deserves taxonomic isolation from its sister peaks. A particular characteristic may be more frequent in one taxon than another, absent altogether, or cryptic; and an assumption is made by the taxonomist practising a level of pattern cladistics when a new species has arisen (Brady, 1982). If this is accepted, then it is the taxic homologies, which are based on descendants rather than transformational homologies, that are defining the phylogeny rather than just seeking to explain the genealogy.

Taxonomists also must deal with a level of contingency in delineating taxa (Chambers, 2012). There is a level of inference, based on evidence at hand that is used to generate the essences that define the organism state and then are restricted further into the kind. This involves a shift from a search for differences to an examination of commonality and the seeking of sub-patterns, or character essences, which form the conflux of axes unifying them (Kitcher 1981). The determination of which essences form the best guide to the determination of an organism state and the kind is a matter of relational taxonomic subjectivity (Okasha, 2002; Devitt, 2008). This reflects the reality that structural essences are innately ambiguous, comprised of an unknown number of transitions, possess an often-cryptic single origin, and may have undergone a level of evolutionary reversal (de Pinna, 1991). Therefore, the approach taken in the determination of a discrete kind, which represents a wider organism state, will be highly dependent on the species conceptual approach that is being utilised by the taxonomist. Again, it is worth noting that the conceptual approach to species is often restricted by a rigid adherence to an ideological stance that blinds the taxonomist to the real phylogeny.

There is a plethora of rigid methodological approaches enabling discrimination of the kind. Many of these methodical approaches to species conception are based on the single individual and are mereologically formulated, and all have the underlying drive to find exclusivity in definition (Hull, 1980; Kornet, 1993; de Pinna, 1999). This gives rise to the problem faced with the defining of the evolutionary unit and the nature of a species itself. Further, this problem can be reduced to one of taxonomic demarcation of inclusiveness once separation based on the components of the organism is used to aggregate and generate the populations (Hull, 1980). Notwithstanding the need for definitional exclusivity, species can also be considered as a set of organisms with a unique relationship that forms a natural heterogeneous individual (Kitcher,1984a; Ereshefsky, 1992).

Irrespective of the species concept that is chosen by the taxonomist, there are four basic characteristics that must be met in order to fulfil the needs of communication of the natural world. First, there needs to

be a reality, or an actual spatio-temporal existence, even if this is unobservable (Cracraft, 1987). Second, the species needs to have a level of individualisation and mutual exclusivity, enabling a demarcation of it from other organisms (Cracraft, 1987; Kornet, 1993). Third, there needs to be irreducibility, such that the entity cannot further be divided and therefore forms a basal unit of taxonomy (Cracraft, 1987), with subspecies used as recognisable cryptic forms of a species complex and not basal taxonomic units in themselves (Maxwell & Dekkers, 2019). Finally, the species must offer a level of recognisable comparability to allow for systematic evaluation and the discernment of evolutionary history (Cracraft, 1987). The individualisation of a species can be problematic, particularly at the boundaries where the descriptive essences chosen to create the definition stray from the kind, obscuring the recognisable compatibility needed to generate a phylogeny. However, taxonomic realism can be achieved only when the taxonomist rejects limiting the definition of species by adherence to dogma and accepts that nature does not differentiate itself by a single unique classificatory unit or set of definitions inherent to a particular species concept (Ruse, 1998). Therefore, species-as-taxon are individuals formed out of a class consisting of a population, reflecting the reality that species are a taxonomic concept and not a category (Wiley, 1980).

The need to adhere rigidly to a single concept, and the ideology that once a species has been defined it is immutable, can hinder the greater understanding of the natural world (Knapp, 2008; Lugadha et al., 2018). There is a long historical acceptance that no single concept best encapsulates the idea of species, and that there is a need to utilise the way that is optimised to achieve comprehensibility and usefulness for the species to which the applied concept gives rise (Grout, 1938). Therefore, the approach to defining a species and its operation must, as a priority, grant the wider community outside the realm of semantic taxonomy a greater understanding of nature (Cracraft, 1987). Each of the monist species concepts relies on a single universal level of evolutionary units, but each is fundamentally unable to account for the diversity between organisms (Mishler & Donaghue, 1982; Rosindell et al., 2010; Alitto et al., 2019). It is only with a broad pluralist approach to the idea of species as the collective individual that evolutionary relationships can be explained taxonomically (Matos-Marví et al., 2019).

Dealing with subspecies is problematic, and this is reflected in the lack of reference to them in the conceptional literature. This is in part a consequence of the definition given to these lower taxonomic ranks such as temporarily isolated populations that are arbitrarily delimited and fated to reticulate back within other lineages (Frost & Kluge, 1994). However, the problem arises when the taxonomist is faced with making a subjective decision on whether a population is an arbitrary subspecies or a distinctive allopatric population with a distinctive evolutionary trajectory (Frost & Kluge, 1994). This leads to the argument that subspecies are not objective concepts (Groves, 2012). Maxwell & Dekkers (2019) argue that subspecies should be restricted to cryptic species where there are no physically observable boundaries to distinguish between populations; and that where boundaries are observable, species rank is justified.

The elevation of subspecies to full species ranking and the redrawing of existing phylogenies have consequences for the allocation of great reputational capital. This has a direct impact on all fields of biology, particularly the highly politicised fields of ecology and conservation biology (Tan et al., 2008; Frankham et al., 2012; Hey et al., 2003). Therefore, the arguments on the treatment of subspecies are even more controversial than debates over any singular particular species concept, which is why it is so often omitted from species debates. Notwithstanding, species are terminal in nature; thus, a taxonomically defined organism is a species, as it has taxonomical importance irrespective of conception (Maxwell & Dekkers, 2019).

## HISTORICAL SPECIES CONCEPTUAL OVERVIEW

The number of species concepts that are in current use is a reflection of the treatment of the level of subtle distinctive phrasing that authors apply to a preferred concept; and its conceptual refinement is reflective of the lumping and splitting debates over species themselves (Groves, 2012; Mayden, 1999). The major conceptual frameworks proposed to delineate a species are each subdivided *ad infinitum* by individual graduation and augmentation as taxonomists have sought theoretical ascendancy, and have been driven to find the one true universal species theory. Fundamentally, all historical species concepts fall into one of four categories:

1) morphological or phenetical (primarily ahistorical);
2) biological (attribute or mechanism);

3) historical (common descent as the primary delineating factor); and
4) genetic, where nature is viewed as continuous and not discrete (Wheeler, 2007).

Phenetist- or morphological-based species concepts are those in which physical characters are utilised to formulate the fundamental division or class that is used to generate a species. This is fundamentally a classical approach in which there is an innate essence that distinguishes the organism (Mayr, 1987). Phenetic methodologies can be divided into two schools: Typological or Linnaean Species Concepts; and Morphological or Diagnostic Species Concepts.

The biological methodologies all have, at their core, a determination of species based on fitness and inheritance. The argument may be couched in terms of current or future biological isolation, depending on the methodological approach taken, or the current selective benefits a cline may have to its current environment. However, a considerable failure of the biological species methodologies is the need for the redefining of many of the currently accepted species, lumping of reticulating populations, and the application of these concepts to asexual biota (Hausdorf, 2011). There are four principal schools of biological speciation: Biological or Mixological Species Concepts; Behavioural or Recognition Species Concepts; Ecological or Differential Fitness Species Concepts; and Geographical Species Concepts.

The historical species concepts are based on cladistic analyses. They use cladistic tree divisions and are grounded in cleavage in the lineage of an organism, which can be traced, providing a temporal aspect to the definition (Hennig, 1965; Kornet, 1993). Historical concepts can be divided into two approaches, one in which the continuity is the fundamental driver of differentiation; and the other in which the recognition of distinctness predominates. The distinctness of the species as individual in the historical context is conceptualised in fundamental ways such as morphologically differentiable, adaptively distinct, geologically isolated, or tokogenetically isolated (Mishler & Donoghue, 1982). However, even more fundamental is the decrement of species from a delimiting point of divergence; and whether the original species is said to continue or is extinguished in the divergence event (Miller, 2001). A secondary fundamental issue for all historical methodologies concerns the treatment of reticulation among organisms; this gives rise to many of the symptomatic issues concerning biological concepts (Hausdorf, 2011). There are four primary schools of historical speciation: Evolutionary or Unified Species Concepts; Hennigian General Lineage Species Concepts; Historical Continuity or Purist Phylogenetic Species Concepts; Historical Tokogenesis Species Concepts; and Phylogenetic or Historical Semphorantry Species Concepts.

Dissimilarity models have an ideology that species should be considered in terms of the smallest delineation, a mereological approach to the delineation of entities based on similarities contained within the DNA, that has given rise to a plethora of physically indistinguishable cryptic species that should be treated as subspecies (Baker and Bradley, 2006; Mishler & Donaghue, 1982; Stauffer-Olsen et al., 2019; Maxwell & Dekkers, 2019). Ahistorical species concepts seek to find processes of speciation that differentiate sets of organisms. Notwithstanding the approach mode to the species concept, there is an underlying commonality (intrinsic essence) based on a shared analogy and parallel evolution that creates a fundamental natural kind, which is delineated and classifiable (Hull, 1987). There are four principal schools of speciation based on genetic dissimilarity: Structural Species Concepts; Genetic or Genic Species Concepts; Cohesion or Continuous Stochastic Block Model Species Concepts; and Genotypic or Functional Clustering Species Concepts.

## THE COMPLEXITY OF DEMARCATION

One of the challenges facing taxonomists is the determination of the level of difference that is considered significant enough to warrant the demarcation of a species from its sister taxa (Adams, 1998; Schutze et al., 2017). The adherence to a particular species concept limits the potential for the naming of new species (de Meeûs et al., 2003; Schlick-Steiner et al., 2010; Pante et al., 2015). Key to the determination of what constitutes a species is the understanding of the evolutionary trajectory of an organism and the level of reticulation with sister taxa that they may undergo (Adams, 1998; de Queiroz, 2005). However, the determination of future evolutionary trajectories is fraught with the danger of speculation and is often undertaken with a level of subjective evidence of directional change based on comparative phylogeny (Adams, 1998). There is now almost universal consensus that, irrespective of the choice of species concept chosen by the taxonomist, it is the demarcation of a distinctive evolutionary trajectory that unifies all concepts (de Queiroz, 2007).

The construction of phylogeny and the determination of species are often based on the sampling of taxa from an existing preconceived pool of organisms. These pools are derived from taxonomic assumptions that are based on existing notions of what species exist, and characters are drawn from a checklist of that group (Barraclough & Nee, 2001). This invariably opens the process of phylogenetic reconstruction to be based in the existing taxonomy, and invariably leads to the confounding and completely arbitrary splitting-lumping conundrum (Barraclough & Nee, 2001). The taxonomist seeks out the patterns of recurrence in nature and then makes the internal judgement of the significance of that pattern (Hey, 2001). Whether species are lumped together, or the level of variation is significant to enable the distinguishing of separate entities, it is conducted at the subjective judgement of the taxonomist and the weighting given to differing characteristics they determine to be consequential (Casanova, 2013). The approach taken in the determination of consequential characteristics is often biased by the discipline or taxonomic group with which the taxonomist is working and their requirement for taxonomic indicators (Kunz, 2002; Frankham et al., 2012). This invariably leads to a set of conditions, or criteria, that are used to generate the concept that is applied in the species diagnosis, often to the exclusion of all other species concepts. If species are comprised of multiple populations that are spatio-temporally separated with individual destinies either to reticulate, speciate or go extinct, then it is clear that there is no one conceptualised force that explains all the potentialities of divergence. Consequently, no one single species concept is able to encapsulate the entirety of the collective essences of the amalgamated organism clade to meet the needs of the taxonomic masses (Haveman, 2013).

One major failing with a hypothetical species is that the historical clustering of organisms that can be well defined and used to generate the spatio-temporal point at which a species is delimited creates the problem of omitting transitional forms (Girard & Renaud, 2011). Similarly, populations may be heterospecific and may be part of more than one species by definition (González-Forero, 2009). Heterospecificity is one of the major problems when demarcating the boundaries of agamic groups and is a primary reason that most species concepts omit an argument on asexuality (Hausdorf, 2011; Haveman, 2013).

Discrete discernment of kinds, which are sound in their spatio-temporal position and are not singularly based upon particular apomorphs, will give rise to the collective individual and offer basal soundness to any clade (Baum & Donoghue, 1995; de Queiroz & Gauthier, 1994). The monist argument that pluralism leads to confusion through a lack of intrinsic meaning in the term 'species' can be overcome when the taxonomist is explicit in the method and conceptionality (Schlick-Steiner et al., 2010). The use of essentialistic pluralism delineates a set of organisms from the natural world at a particular spatio-temporal point and that contains enough meaning to enable discrimination and thus allow for an organism's taxonomic discernment. It is the failing of hierarchical taxonomic theory that, even if kinds are well defined, there remains a distinct lack of evolutionary theory in the relationships between higher taxa.

## REVIEWING PLURALISM

The essentialistic pluralist approach does not seek to tie the taxonomist down to one species concept, but rather enables a choice in definition to be applied based on the uniqueness of the characteristics of the organism as a set, and thus is an extension of the reality that taxa are entities that currently exist, or have existed, within a temporal space and are in need of demarcation and explanation (Kitcher, 1984, 1984a). This is the theoretical underpinning for integrative taxonomic practice with its universality in choice of criteria with maximum defensibility of demarcation (Yeates et al., 2011; Schutze et al., 2017), but further adds a spatio-temporal constraint. This temporalism must still include innate references to the organisms that are historically related, as the removal of the historical context itself reduces the meaning of species and is a major cause of inconsistency, even in the face of disconnectivity of lineages (Ereshefsky, 1992). Ereshefsky (1992) noted that pluralistic species concepts allow for the coverage of the multiplicity of evolutionary forces that drive divergences, such as interbreeding, selection, genetic homoeostasis, common descent, and developmental and ecological isolation: this conceptional approach formed the basis for integrated taxonomy (Schlick-Steiner et al., 2010; Pante et al., 2015; Solari et al., 2019). This reflects the reality of the natural world. Mayr (1987, p. 149) argues that the pluralist approach failed through the inability to distinguish the species category and the species organism: "mammals, hairy caterpillars, hairy seeds of certain plants and other hairy objects, would make a legitimate set" and therefore a heterogeneous species. Mayr (1987) fails to recognise that pluralist species are

discrete individuals, a collective set bounded in time, having a real meaning used to describe the observable and not categorical abstractions. True pluralism needs to be free from any structural boundaries and overcomes the underlying complexities of the species argument to enable a taxonomist to enunciate a greater accuracy in the phylogenetic classificatory process. This is achieved through the enabling of individuality through the recognition of set complexity (Lombard et al., 2010).

Mishler & Donaghue (1982) argue that species should not be separated from higher ranks, but form a natural extension of them; and should be viewed as assemblages united by descent, not as individuals. However, the acceptance of individuality enables the taxonomist to draw a spatiotemporal line as to the kinds that are to be used in classification. These kinds then enable the understanding of higher ranks based on evolutionary relationships. Not accepting species as individuals means that the basis of higher taxonomy is grounded in arbitrariness and thus rendered meaningless. The term 'exclusivity' can be associated with kinds and is the foundation of the coalescence theory, that biological entities are closely related to a particular group and thus objectively discernible (Baum & Donoghue, 1995).

Mayden (1999) conceived the consistent approach of species delimitation, in which there was an encouragement of cooperation in the understanding of diversity and for conceptual monism. At the heart of this monist approach is the recognition of the species based on a description or diagnosis that is used as the criterion for demarcation, which is then defined by a concept (Mayden, 1999). However, one universal failure of species concepts is the lack of conceptual definition, which should be resolved before the population can be determined (Hausdorf, 2011). This is probably more relevant to species delineation than any conceptual approach. Hey (2006, p. 459) argued that "detection protocols are not concepts" and the taxonomist needs to separate the criteria for delineating species from the "theoretical understanding of the way species exist", that is, the concept. This idea places the recognition of a species outside the confines of any preconception of how a species should be conceptualised. There is a need for species pluralism, which is the overarching monist concept, and has been the underlying goal of all species conceptual arguments.

A fundamental pluralistic approach seeks to bring an overarching conceptuality to the differing species concepts in which the goal was not an abandonment of any one concept *per se*, but rather an acceptance that each concept is an operational tool to be used in the discovery of the species (Mayden, 1999). The determination of the evolutionary trajectory has priority in species demarcation, and the species concept applied is merely the tool to enable recognition of that evolutionary event at a point in time.

One of the major issues that distinguishes species concepts is the determination of whether the process of evolutionary separation has been finalised, or is an on-going process marked with a lack of complete biological separation of the populations. There is a growing shift to accept species as evolutionary populations and a realisation that criteria for delimiting these species cannot be restricted, but rather need to be based on factors that are outside the confines of any one isolating biological property (Naomi, 2011). That is, under essentialist pluralism, the taxonomist may be aware of an essential characteristic that makes a species unusual and distinctive. This then forms the basis for a criterion, and integrated taxonomy allows the taxonomist to be free to determine a conceptual approach that provides the framework for naming a new taxon based on that distinctiveness. Therefore, under essentialist pluralism, there is no restriction on which concept is used to delineate an organism. However, there is a need to restrict the species to a point in time with a defined morphospace. Thus, this conceptual freedom demands that taxonomists accept an obligation to be true to the phylogeny and thus must justify the choice of species concept, both in terms of a criterion for distinction, as well as offering an explanation for the cause of that species' existence, as well as stating its relationships with others placing the organism in context.

## PHILOSOPHICAL FAILINGS

Many of the reviews of species concepts fail to explore essentialist arguments, or when this exploration is carried out, it is with the basic premise that all essentialist arguments are phenetic. However, one of the major failings of the current essentialist approach to species criteria is the decision that species concepts are facts and, therefore, acceptable to be used taxonomically (Hey, 2006). This clearly is the crux of the problem. Taxonomists fail to recognise that species have two parts: the criteria with the distinctive hypothetical process of species delimitation with the rigidity to a concept; and the conception itself, which is hypothetical (Paul, 2002). The natural consequence

of failing to recognise these two parts explains why the treatment of complex taxonomic clusters, such as agamics, is overlooked in conceptual formulations. It is only with integrated taxonomy that the taxonomist is freed from the theoretical constraints of taxonomic rigidity imposed by doctrinal adherence to a single hypothetical species concept and is able to explore the criteria of the real organism necessary to impart taxonomic meaning (Schlick-Steiner et al., 2010). Essentialistic pluralism, through the use of integrated taxonomic practice, provides an explicit spatio-temporal point necessary to impart taxonomic meaning; and therefore, provide reference points for evolutionary contextualisation as an organism morphs through time.

Fundamentally, species need to be conceptualised outside of taxonomic classificatory systems as they fall outside of systematic hierarchical arguments (Dubois, 2011). Thus, the use of subspecies is arbitrary, with all-natural entities worthy of species consideration if they are observably distinguishable, even if this is only spatially significant (Maxwell & Dekkers, 2019). This is because species, although hypothetically chosen, remain real entities, represented by collective individual populations and not just intentional meanings derived by the taxonomist, which is inherently what higher classifications are (Ghiselin, 1974; Hull, 1976). This raises a point of contention: if species are real, why are many of the concepts that are used to define them based on unreal or non-causal criteria? This leads to a complexity in conceptual realisation and invariably to conceptual misunderstanding, a problem absent in higher taxonomic arguments that have no physical reality or place in species debates (Stamos, 2003).

## IMPLICATIONS FOR DISCERNING SPECIES

Recent evolutionary essentialism has, at its core, a sense of indeterminacy in the definition of what constitutes a species (Devitt, 2010). This indeterminacy can be countered if a species is first viewed as an individually unified population representing hypotheses that explain the convergence of both intrinsic and extrinsic structural essences. The acceptance of essences as having intrinsic and extrinsic properties highlights one of the theoretical failings of the current anti-essentialism debate, where species are delineated primarily on intrinsically pseudo-phenetically inclined parameters (Lewens, 2012). The intrinsic and extrinsic structural essences of collective higher taxa particular to a clade are used to form a continuum, the essence matrix, from which the organism state is then delineated. This organism state represents a static cross-section in the evolutionary history of a real population that contains all the phylogenetically restricted character essences that are exhibited by the organism and allows for group delineation (Pleijel & Rouse, 2000; Figure 2).

The evolutionary progression of the organism is phylogenetically constrained by the evolving and limiting structural essences. This idea of structural essences forming a unified entity is in the true Aristotelian tradition (Dumsday, 2012). Notwithstanding, the concept of phylogeny generated by the new evolutionary synthesis necessitates that these structural essences are viewed as spatio-temporally mutable. Therefore, structural essences are to be seen as historical and, possibly, variably pluralistic in nature, and in turn they reference the wider immutable spatio-temporal.

## CONCLUSION

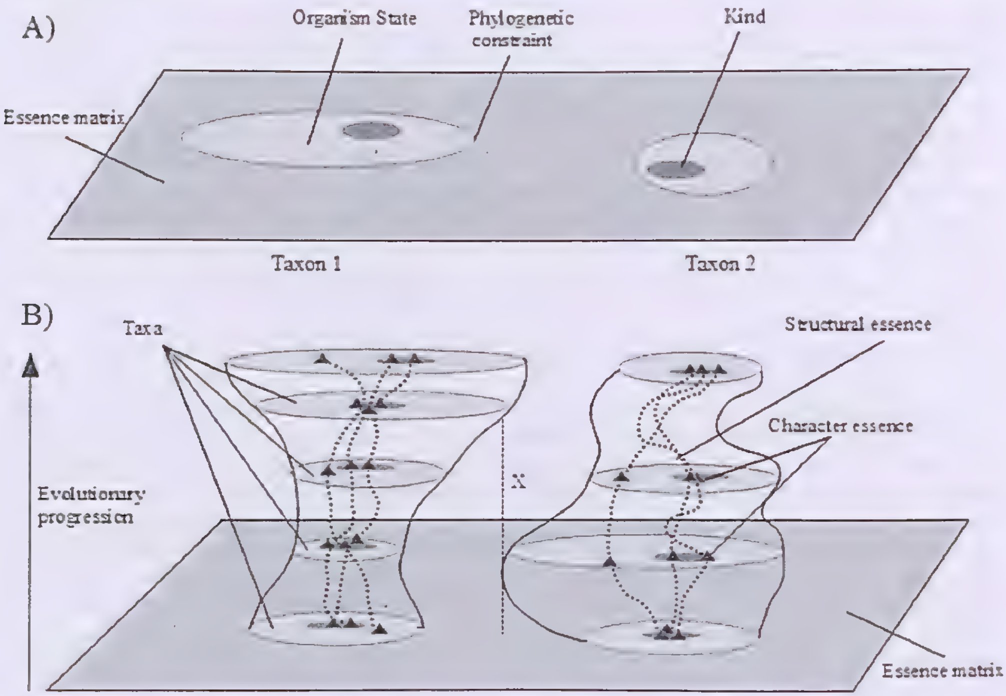
The reliance on species relational concepts without an evolutionary context, and the linking of phenetic ideology with the concept of essence, is a failing in much of current essentialist and anti-essentialist arguments (Lewens, 2012). It is only the understanding of the structural essence itself, with knowledge of the driving forces and processes that gave rise to that essence, which enables the discernment of analogies and reveals the true phylogenesis of an organism. It is how the cladist or taxonomist deals with the delineation of stages in the evolutionary progression of structural essences that then forms the basis of the restriction of the organism state and how the kind is defined. This is then consequently reflected in the criteria used in the choice of model of speciation and conception that is utilised to impart taxonomic meaning to all hypothetical entities called a species.

Once the taxonomist has distinguished the evolutionary trajectory of an organism based on any criterion, there is freedom to determine an appropriate conceptual approach to justify the recognition of the new species. The only requirement that is placed on the taxonomist is the need for explicitness in the justification for that conceptual choice. Essentialistic pluralism generates hypothetical terminal taxonomic units from which phylogenies are then constructed. Therefore, delimitation of species has a critical impact on the understanding of evolutionary biology where they form the spatio-temporal kind within an essence matrix, the continuum of evolutionary descent. The use of essentialistic pluralism, with its unrestricted

approach to conceptualisation of what is a species, using integrated taxonomy with spatio-temporal limitations, allows the taxonomist the freedom to express a unique approach to exploring phylogeny without the shackles of rigid necessity to declare adherence to a single species concept. Essentialist pluralism is, therefore, the gold standard for universality and is the conceptual monist Holy Grail that has underpinned the rhetoric of species debates for centuries. It is only the fear of loss of reputational capital by taxonomists who have spent their lives arguing for one concept that implicitly holds integrated taxonomy back from achieving universal acceptance.

The conceptual monist argument that pluralism leads to confusion through a lack of intrinsic meaning in the term 'species' can be overcome when the taxonomist is explicit. The use of essentialist pluralism delineates a set of organisms from the natural world that contains enough meaning to enable discrimination and thus allow for an organism's taxonomic discernment. It is the failing of hierarchical taxonomic theory that, even if kinds are well defined, there remains a distinct lack of evolutionary theory or the concept that the describing author had for the relationships between higher taxa. Therefore, essentialistic pluralism addresses the issue of species demarcation at its core. Once the taxonomist has distinguished the evolutionary trajectory of an organism based on any criterion, there is freedom to determine an appropriate conceptual approach to justify the recognition of the new species. The only requirement that is placed on the taxonomist is the need for explicitness in the justification for that conceptual choice. This invariably makes sub-specific ranks taxonomically meaningless, and invariably recognises all ranks below species as individual evolutionary lines worthy of full species

FIGURE 2. The two fundamental essentialist ideologies: A) the phenetic approach, which does not include evolutionary progression; and B) the essential pluralist approach, in which structural essences are used to delineate an organism state with character essences in temporal stasiogenesis within the evolutionary continuum. Organisms may show similar structural essences (X) as a consequence of occupying the same position within the essence matrix, this may arise from a mechanism such as convergence. Each of the taxa that overlaps can be readily distinguished from the other through an understanding of their evolutionary progression. The essence matrix is the the evolutionary potential of an organism that confines the character limits.



recognition. That is, subspecies should be used for cryptic species and the examination of clinal variations (Maxwell & Dekkers, 2019). This leads to an argument for the use of mononomial terminal taxonomy. Further, this new taxonomic approach to species conceptualisation has significant implications for the assignation of higher taxonomy, which is often more a reflection of the lack of 'room' at the lower cladistic levels under the draconian Linnaean rigid methodology which is being challenged with the introduction of phylogenetic nomenclature under the PhlyoCode. Essentialistic pluralism and terminal taxonomy present a new approach to species and are natural extensions of using rank-free phylogenetic taxonomy in higher classification with spatio-temporal restrictions.

The Linnaean system is a set of informal hierarchies that simply groups organisms into clusters based on taxonomic preference, which are then named relative to each other without the need for historical consideration of any higher relationship. This lack of relational meaning can be traced back to the fact that relational understanding of higher systematics fundamentally eluded Linné. The need to explain evolutionary trends has become an important facet in the modern evolutionary synthesis, and such evolutionary processes and patterns need to be reflected in the nomenclature. This contextual ambiguity has left Linnaean taxonomy struggling to demonstrate true historical relationships between the taxa within clades. Therefore, there is a strategic need to revise the lower order taxonomy and in particular revisit the idea of uninomials to avoid arbitrary cladistics rankings.

Essentialistic pluralism addresses the issue of species demarcation at its core. Once the taxonomist has distinguished the evolutionary trajectory of an organism based on any criterion, there is freedom to determine an appropriate conceptual approach to justify the recognition of the new species. The only requirement that is placed on the taxonomist is the need for explicitness in the justification for that conceptual choice. This invariably makes sub-specific ranks taxonomically meaningless and recognises all ranks below species as individual evolutionary lines worthy of full species recognition. This leads to an argument for the use of terminal taxonomy to be declared to anchor all levels of nomenclature. Further, this new taxonomic approach to species conceptualisation has significant implications for the assignation of higher taxonomy, which is often more a reflection of the lack of 'room' at the lower cladistic levels under the draconian Linnaean rigid methodology. Essentialistic pluralism and terminal taxonomy combined present a new approach to species, and this is a natural consequence of using rank-free phylogenetic taxonomy in higher classification.

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## AUTHOR PROFILE

Stephen Maxwell is a doctoral candidate at James Cook University researching radiation and reticulation of gastropods during the recent interglacial cycles. He has a keen interest in the philosophy of science in relation to speciation theory, with a goal of uniting nomenclature and phylogenetics. Prior to undertaking studies in the sciences, he studied history and classics and has a passion for archaic Greek poetry.

# BRISBANE'S FAMOUS EARLY ASTRONOMER: CAPTAIN HENRY O'REILLY

ANDERSON, P.[1]

In this paper I have researched the life of Captain O'Reilly while he was living and working in Brisbane, but particularly focusing upon his astronomical activities. In order to better accomplish this, I needed to learn something about the man himself. I became very impressed with his attributes – competent, capable and courteous – and feel sadness that he was not allowed (dying as he did at 52) a couple more decades of life. He left a fine legacy. In my view he can be regarded as the first Queensland (non-indigenous) astronomer. My thanks go to Steve Hutcheon for his indefatigable research efforts; Bill Kitson, former Senior Curator of the Queensland Museum of Lands, Mapping and Surveying; the descendants of Henry O'Reilly; the State Library of Queensland; and especially the 'Trove' service, which has made so much material from early newspapers and publications so readily accessible on the internet.

Keywords: astronomical observatory, astronomy, history Brisbane, history Queensland, O'Reilly, Henry O'Reilly, timekeeping, time service

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## O'REILLY'S MOVE TO AUSTRALIA

Henry George O'Reilly (22 February 1824 – 18 February 1877) was born in Dublin and emigrated to Sydney. Throughout his life he simply used his first name, 'Henry'. His grandson Henry George O'Reilly (1882–1959), often referred to as 'Henry George', clearly indicates a family connection with the name 'George'.

FIGURE 1. Captain Henry O'Reilly when in employment as a ship's captain (State Library of Queensland).

Henry's descendants hold some of his personal diaries. The diary entry for 1 November 1852 states: "So now with a start of £30 in my pocket and an implicit trust in Divine Providence assisted with my own determination of a strict integrity of conduct, sobriety and a determined perseverance of doing my duty for my next employers, as I have always endeavoured to do for my past ones, I sold my traps (belongings, baggage) and bid goodbye to all friends and stepped on board the 'Athlone' on Monday."

O'Reilly had been trained as a master mariner. In Australia he captained a number of Australasian Steam Navigation Company ships. He was the regular captain of the steamer *Telegraph*, plying between Sydney and Brisbane, and made a total of 320 such voyages without incident. (This 367-ton paddle wheeler was later wrecked at Camden Haven, south of Port Macquarie in 1867 – see Figure 2.)

In 1859, O'Reilly had the pleasure of taking the first Governor of Queensland, (Sir) George Ferguson Bowen, from Sydney to the newly independent colony.

## THE MOVE TO BRISBANE AND EMPLOYMENT

By 1859, when Queensland became a separate colony, Brisbane had a population of 5000. This increased to 19,000 by 1871, 37,000 by 1881, and a leap to 88,000 by 1891. Cross-river traffic was by ferry until the first Victoria Bridge was constructed in 1865.

FIGURE 2. Wreck of the Australasian Steam Navigation Company Steamer *Telegraph*, 1867.

Unfortunately, being made of wood, it collapsed due to woodworm in 1867. Its replacement, an iron bridge built in 1874, lasted until the great flood of 1893. This gives a perspective of the times. Figure 3 shows the city as Henry O'Reilly would have known it when he first came to live there. South Brisbane was a separate municipality until 1924.

On 4 December 1863, O'Reilly relinquished his captaincy of the *Telegraph* to take up the position of Manager (Managing Agent) of the Australasian Steam Navigation Company's Brisbane Office. He had assumed duty by mid-month and remained until ill health forced him to retire from business activities some months before his passing from cancer in early 1877. Therefore, his career in Brisbane was short – less than 13 years.

The company headquarters in Brisbane was a fine, stone building at 193 Mary Street. It was completed by late November 1866 and substantially rebuilt in 1889. Figure 4 shows it as it was during O'Reilly's tenure.

In a newspaper report as the building was nearing completion, Messrs O'Reilly and Pritchard* are described as the company's agents, and the three levels of the building (about 60 × 33 feet in dimension – 18 × 10 metres) are described, as well as its other usage as a bonded warehouse for the storage of dutiable goods (Anon., 1866b).

The architect of the building is stated to be Benjamin Backhouse (builder A. Tupper), and it is interesting to note that two years later, in 1868, O'Reilly purchased his 'Toonarbin' property from Backhouse.

## O'REILLY'S RESIDENCE 'MONTPELIER' IN BOWEN HILLS

As previously stated, Captain O'Reilly lived in Sydney and regularly plied between Sydney and Brisbane, making 320 trips in all without incident. Whether it was because Sydney was more closely settled (and expensive), or for some other reason, O'Reilly had before 1861 already purchased a 7-acre, 37-perch block of land in Brisbane. This property had a large, flat crown at 160 feet altitude with a fine view of the river and the surrounding area. The area is now called Bowen Hills, but it was called 'O'Reilly's

* Alexander Brown Pritchard was in partnership with O'Reilly. Both were confirmed as agents by the ASN Company, effective from 2 April 1866. Between late April 1866 and mid-November 1867, O'Reilly was overseas, principally for medical reasons. The partnership was dissolved on 9 December 1867, O'Reilly taking over the business of the partnership and paying the accrued debts of more than £4,389 owing to the company. Pritchard is subsequently described as insolvent. On the face of it, it would appear that Pritchard accumulated at least the bulk of these debts during O'Reilly's absence, and as the solvent partner, O'Reilly was obliged to repay them upon his return. He did this after dissolving the partnership.

Hill' when he built a very substantial house upon it. Tenders were called in January 1861 for construction of this house, and by August 1861 it was presumably complete, or nearly so, because Mrs O'Reilly arrived from Sydney in that month. In February 1862, sales advertisements for nearby blocks reference O'Reilly's new house as a geographic reference point, and in June 1862 there was a reference to Mrs Henry O'Reilly at that address, named 'Montpelier'. For several years the family lived in this house, before moving out and renting the property. A story passed down within the family is that Mrs Mary O'Reilly would always light a lamp on the Montpelier verandah when the Captain was coming up the river at night so he could see it.

The property was still in O'Reilly's hands when, in March 1865, a birth notice appeared in the name of 'Cairns' at this address. Then, in July 1867, it was let to the Hon. John Watts, but it soon became vacant. In February 1868 the house was advertised for rent again, last having been let to a Mr W. B. Tooth. Finally, on 5 June 1869 (after O'Reilly had purchased 'Toonarbin' (see below)), it was advertised for sale, with a full description of the house – constructed of stone and cement rendered (the present term) with 12-foot verandahs. The surrounding block containing fruit trees and flower gardens was also described. It was noted that the house was occupied at the time by the Colonial Secretary, the Hon. A. Hodgson, indicating it was a very fine home.

A name remaining from this period is 'Montpelier Road, Bowen Hills' (see Figure 5).


FIGURE 3. Ham's Map of Brisbane in 1863.

FIGURE 4. Australasian Steam Navigation Company's Brisbane Headquarters, ca 1875 (State Library of Queensland).

FIGURE 5. View ca 1872 from O'Reilly's Hill (Bowen Hills) over Newstead House (State Library of Queensland).

## O'REILLY'S INNER-CITY BRISBANE RESIDENCE

A notice in *The Brisbane Courier* (Anon., 1885) advertised the sale by auction of the 193 Mary Street property and surrounding warehouses and wharves. In the description is: "... while on a part of the frontage in Felix and Margaret Street is erected a very commodious residence occupied by the well-known popular manager of the company, Wia. [*sic*] Williams esq. ..."

On the basis of this advertisement, it may well be that managers of the Brisbane Office were expected to live on site. Henry O'Reilly had taken up his managerial appointment in December 1863. The company's new substantial business premises at 193 Mary Street were completed in late 1866 (refer again to Figure 4). It is reasonable to assume that the manager should have been on site, in any event during the planning and construction period; however, O'Reilly was absent overseas from late April 1866 to mid-November 1867, principally for medical reasons, and his partner Alexander Brown Pritchard appears to have acted as manager in his absence.

The previous manager, Mr G. D. Webb (who retired at the end of 1863 to be replaced by O'Reilly), was still in residence beyond 10 March 1864, because an advertisement on that date for a cook and laundress at that address referenced Mrs Webb. However, the Webbs moved during the year to a new house they were building near Montpelier and the O'Reillys moved in, because there was an advertisement on 19 December 1864 by Mrs O'Reilly for a respectable girl as a general servant, giving the same Felix Street address.

There was a similar advertisement by Mrs O'Reilly for the same address in August 1872.

It is a reasonable conjecture that apart from the aforementioned period in 1866–1867, the O'Reilly family lived in Felix Street between the years 1864 and 1872 (at least). It may have been even more financially economical to do so in the period (1864–1869) during which they rented out the Montpelier property.

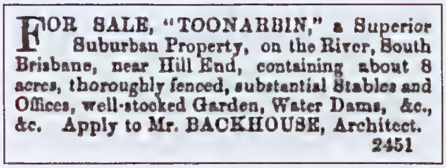
## O'REILLY'S RESIDENCE 'TOONARBIN' IN HILL END

In 1868, O'Reilly purchased 'Toonarbin'* from Benjamin Backhouse, a well-known colonial architect. This property and surrounding land of 8 acres were situated on what is now Dornoch Terrace, Hill End. Identical advertisements for the sale of the property appear in *The Brisbane Courier* in September and October 1868 (see Figure 6). By that time, Backhouse was already in the process of moving permanently to Sydney, because the sale of the furniture, etc., at his residence at North Quay in the city was held by auction on 26 October.

The evidence is that Toonarbin had been built several years before it was purchased by Captain O'Reilly and, indeed from all accounts, had been designed and constructed by Backhouse (see Figures 7 and 8).

* Benjamin Backhouse named the property 'Toonarbin' after a manor in Henry Kingsley's early Australian novel, *The Recollections of Geoffry Hamlyn*.

FIGURE 6. *The Brisbane Courier* 1868 advertisement for sale of Toonarbin.



**FOR SALE, "TOONARBIN," a Superior Suburban Property, on the River, South Brisbane, near Hill End, containing about 8 acres, thoroughly fenced, substantial Stables and Offices, well-stocked Garden, Water Dams, &c., &c. Apply to Mr. BACKHOUSE, Architect.**
**2451**

A fit-out was conducted, possibly before occupation, as the O'Reillys did not take up residence until after 1872. Captain O'Reilly was certainly well established in Toonarbin at the time of his death in 1877, and it became the long-term family home until 1926.

Why didn't the O'Reillys move to Toonarbin earlier? Apart from the pressure for Henry's continued presence in his managerial position, there was certainly in the early years the small matter of crossing the river to and from the Hill End home. Though there were ferries, it would have been time consuming to make this trip twice daily. (As mentioned, the previous wooden bridge crossing the river had collapsed due to woodworm in 1867, and the new iron replacement was not completed until 1874.)

The property extended down to the Brisbane River. O'Reilly increased his holdings to 24 acres by purchasing surrounding land. The area was known as 'O'Reilly's paddocks' and was often used for picnics and children's parties, certainly as late as 1913.

After O'Reilly's death in 1877, his son Charles O'Reilly (Charles John O'Reilly, 1854–1925 – see Figure 9) and family members lived there until 1926 when the property was bought by Archbishop Duhig and converted into a convent. Alterations were made and a brick exterior added (see Figure 10). Some of the surrounding land had been subdivided and sold in 1912, and the remainder was sold in 1928 (see Figure 11).

In recent times the house, now in private ownership, has been heritage listed and restored. It is available for public inspection (see Figures 12, 13 and 14).

FIGURE 7. Toonarbin and the future Dornoch Terrace, 1880s.

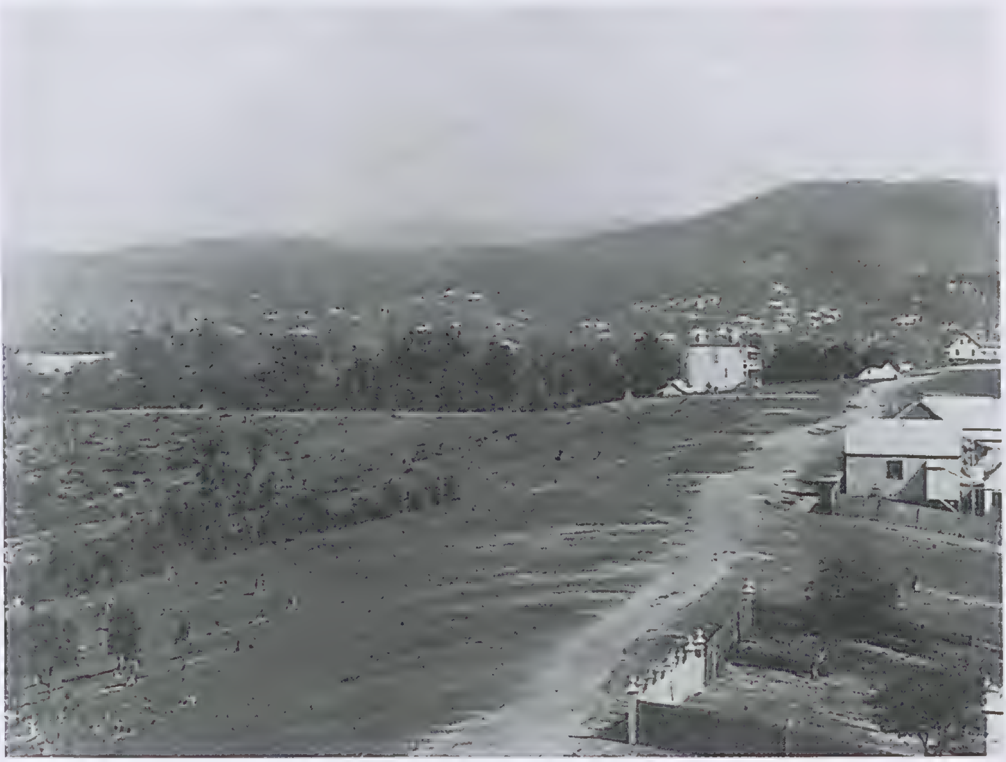


FIGURE 8. Toonarbin, around the time of O'Reilly's residence.

FIGURE 10. Recent image of Toonarbin with brick cladding from convent days.

FIGURE 9. Charles O'Reilly, son of Henry (*Sydney Morning Herald* cartoon).


**O'REILLY, CHARLES JOHN.**

Carrier. Bonded Warehouseman and Agents (Custom). Established 1866. Born Sydney, N.S.W., November 13th, 1854. Son of Henry O'Reilly and Mary Smith of Dublin, Ireland. Came to Brisbane 1860. Member of C.T.A., Queensland and Brisbane Clubs.

FIGURE 11. 1928 Subdivision advertisement.

FIGURE 12. Toonarbin ballroom after restoration.

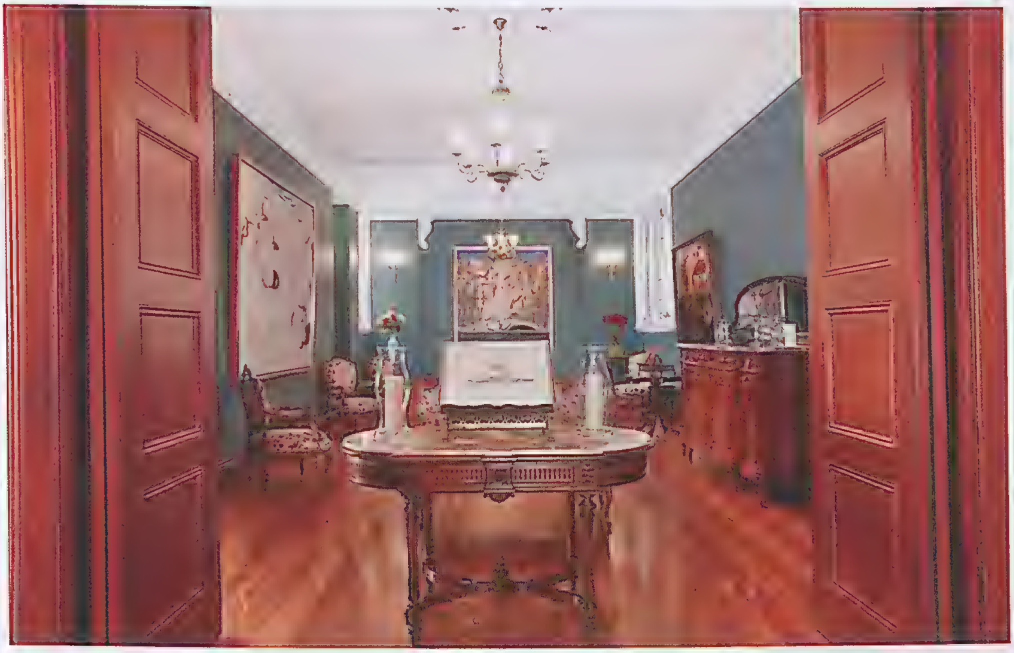


FIGURE 13. Toonarbin drawing room after restoration.

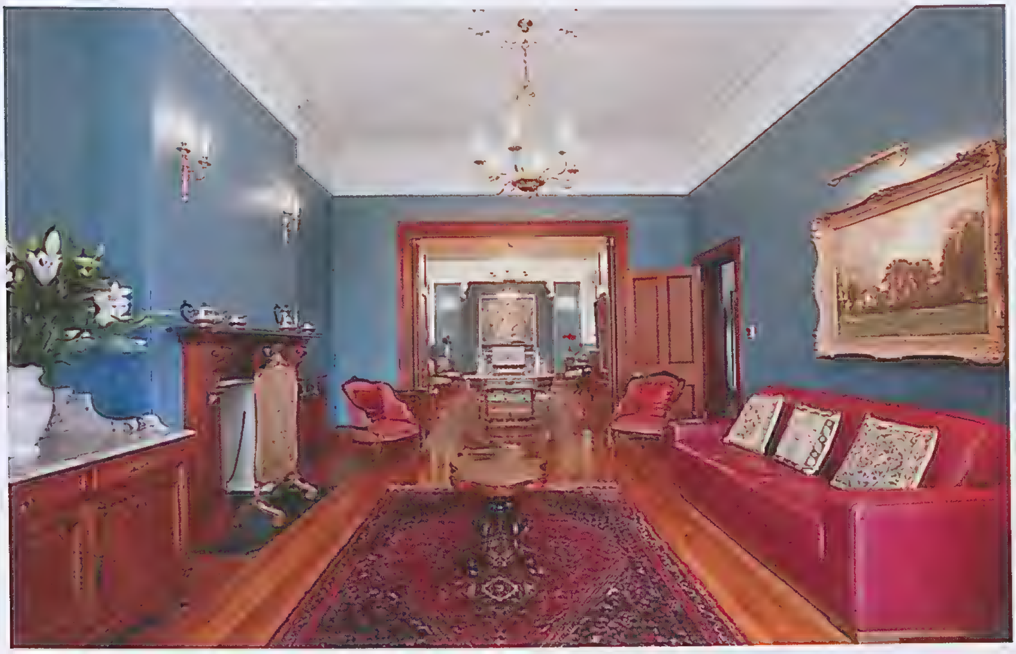


FIGURE 14. Toonarbin study after restoration.

## THE BRISBANE TIME SERVICE AND O'REILLY'S POSSIBLE INVOLVEMENT

As O'Reilly was a ship's captain from 1861 to 1863 (though from late 1861 nominally living at Montpelier), it is extremely unlikely that he would have been involved in the provision of a public time service involving the dropping of a 'time ball' from a mast on the Old Windmill building on Wickham Terrace, which commenced in October 1861 (see Figure 15).

When a 'time gun' was installed at the same site in May–June 1866, O'Reilly was absent from Brisbane. As mentioned, he was overseas between April 1866 and November 1867, so it was extremely unlikely that he was involved with the time gun service either.

A press article (Anon., 1881) decries the lack of being able to obtain accurate time in Brisbane, with hopes for this to be rectified when O'Reilly's observatory, then under reconstruction at its new site on Wickham Terrace, was brought into operation. It was stated that the transit method would be used to determine time. One problem with the inaccurate service then existing seems to have been the accuracy of the Post Office clock which provided the time for the time gun. It was not being carefully set. Certainly during the O'Reilly era, it was well known that he kept very accurate time. But any connection he had with the public time service is clearly tenuous.

Therefore, though his name has been mentioned, it is unlikely that O'Reilly had much involvement in the public dissemination of accurate time. For nearly five years commencing late 1871 or early 1872 when he operated his observatory, he determined and maintained very accurate local time himself, and as described later in this paper, part of this involved testing the accuracy of marine chronometers brought to him by ship's captains. However, any connection with the established public time service remains tenuous at best, despite suggestions such as the matter immediately following.

As stated, the inaccuracy of the Post Office clock already described gave rise to complaints. A suggestion in a letter to *The Brisbane Courier* proposed an alternative time source and stated in part:

> My second proposition is to negotiate with Captain O'Reilly for him to transmit from his observatory, by means of a telegraphic key, to the Telegraph Office, where there is a first-class clock,

the information that 1 o'clock has arrived, and let some official there fire the gun by electricity, and also transmit to the stations where required the true time of 1 o'clock. This plan is adopted in New South Wales for the information of the up-country stations. I need scarcely add that the observatory of Captain O'Reilly is complete, and more than sufficient for the requirements of Brisbane for many a year (Watchmaker, 1875).

Later, of course, from 1881 (after his death), O'Reilly's relocated observatory, now on Wickham Terrace, was pivotal in providing the time service by the transit method for nearly the next 40 years.

*The Brisbane Time Service*

How did the public time service, so necessary for commerce and industry, operate in Brisbane?

Records indicate that the daily dropping of a time ball commenced at 1.00 pm on 14 October 1861. The ball was dropped from a mast atop the Old Windmill on Wickham Terrace (often called 'The Observatory') – again refer to Figure 15. The new Queensland Government had appointed Lt. G. P. Heath RN on the recommendation of A. C. Gregory, Surveyor-General. He was given the task of providing the time for the control of the dropping of the ball until the Sydney–Brisbane telegraph line was completed. This line was opened on 9 November 1861, and thereafter telegraph time was used.

As mentioned, a time gun was later installed at the same site to replace the dropping time ball. This daily time gun service commenced at 1.00 pm on 18 June 1866. The time gun referenced was a 24-pounder, muzzle-loading cannon (quite a substantial weapon) which was one of twelve brought on the immigrant ship *Clifton* in 1862 for the purpose of defending the colony. These guns were maintained at Queen's Park and mainly used for drill purposes, the firing of salutes on ceremonial occasions, and the opening of Parliament. In May 1866, this particular gun was sent to serve as a time gun. In 1873, a shed was erected to protect the gun (Anon., 1873b). There have been several guns over its period of operation, a 32-pounder in the 1870s giving rise to complaints about undue noise and the shaking of nearby buildings when it was discharged. But other citizens complained to the newspaper that they could not hear it when the charge was reduced. It seems you can never please everybody.

A 12-pound Howitzer, reconstructed from component parts found at Fort Lytton, is also referenced.

FIGURE 15. The Old Windmill building, Brisbane, 1933. Note the platform on top and the time ball (Queensland State Archives).

In early 1879, the Postmaster's Department of the Queensland Government proposed to offload the operation of the time gun to the City of Brisbane administration. The City replied that its operation was not within their authority, but that they would be prepared to pay for the gunpowder. Their six-monthly accounts, accessed for the next few years, show expenditure of between £20 and £36 each half year! (Anon., 1879).

The following report (the monkey incident), referring to the "gun loft", was originally assumed to refer to the Old Windmill tower, but another source indicates that the firing was carried out from ground level, so it could more easily refer to the roof frame of the gun shed. Certainly the 1873 shed referenced in a preceding paragraph was built on ground level, as attested to in a later photograph. It is possible that the firing site depended upon the characteristics of the gun in question.

There are some interesting stories about the original time gun, as related by Haynes et al. (1993):

> The gun was fired by a retired sea captain, John Sully, whose son later recalled that on one occasion his father forgot to bring his watch down from the tower and while he was returning for it, one of the pet monkeys, accustomed to sit in the gun loft and observe the daily ritual, pulled the lanyard firing so that the gun went off a minute early.

I suppose the expression 'monkey see, monkey do' would apply!

On another occasion, it is reported that the ramrod broke off and was discharged also; it was found near the People's Palace some 250 metres away. (The current People's Palace building that dates from 1910/1911 is presumably at the same site, on the corner of Ann and Edward Streets. It is 260 metres distant.) This indicates that the blank charge was fired in the general direction of the city centre for most effect.

But the time-sourcing and related arrangements were apparently not satisfactory, and so, from 1881, Queensland determined its own time by the transit method from O'Reilly's relocated observatory on Wickham Terrace. One of the principal reasons for finally removing the equipment from this site in 1920 was its increasing unsuitability for transit time determination. Such transit work then continued in Brisbane at different sites within the city for several decades afterwards, until a unified time service came into being under the province of the Commonwealth Government.

The time service is also dealt with in the Wickham Terrace Observatory section of this paper.

## TOTAL SOLAR ECLIPSE, 12 DECEMBER 1871

The Queensland Government generously allowed the use of one of its ships, the *Governor Blackall*, for an expedition from Sydney to the far north Queensland coast to observe this total eclipse of the Sun. Henry O'Reilly, whose astronomical prowess was already known, was the obvious choice for Queensland representative on this expedition, but pressure of business prevented him. He nominated Sylvester Diggles, whose colourful account pays tribute to the zeal and preparation of the party. But the eclipse itself was a total washout, with thunderstorms and heavy rain all day (Lomb, 2016).

## O'REILLY'S BRISBANE OBSERVATORY, 1871

O'Reilly was residing at the Felix Street company premises (the manager's residence) adjacent to his Mary Street workplace between late 1864 and the latter part of 1872 at least, excluding his aforementioned absence in 1866–1867. In 1871 he constructed his observatory in Felix Street, on company land adjacent to this residence.

There is no record of any observatory at his previous Montpelier or his later Toonarbin residences.

O'Reilly refers to this observatory as his 'new' observatory, though no record can be found of a previous observatory, which was possibly a more modest structure nearby or upon the same site. The 'new' observatory dates from 1871 and would have been complete at the end of that year or early in 1872, and was a rectangular building aligned east–west. There are no good images of the building, but panoramas from a distance, specifically a confirmed 1873 image from across the river, show the building to have had a shallow-sloped roof on the near (eastern) side of the central dome, and a taller section (partly obscured by foliage) on the far (western) side. (See Figure 16. The manager's residence is the substantial building immediately to the left of the observatory. Other images around this period confirm this layout and description.)

A proposed plan (Queensland Railways, 1878) for the Australasian Steam Navigation Company's site shows the east–west outline of the observatory building. This has enabled accurate identification of the alignment and positioning of the observatory.

This observatory, originally situated in Felix Street at the rear of O'Reilly's work building at 193 Mary Street, was stated to be on a small, triangular piece

of land, "Felix Street" being given for its location (Haynes et al., 1996; JOT, 1874a,b). Further discussion on the exterior of the observatory appears in the section of this paper dealing with its reconstruction and use on the Wickham Terrace site.

O'Reilly kept very diligent records of the observatory's cost, and in the period between March and the end of December 1871 he expended an amount of £327 6s 8½d. From this we can assume that the observatory was likely operational from the end of 1871. This amount includes instruments, observatory materials and fit-out, books and other items – even gardening! These accounts include £77 10s for the 4½-inch Ross refractor and £16 for the 20-inch-focus transit instrument, both on 21 April, and £45 for the sidereal clock on 27 December.

O'Reilly was elected a member of the Philosophical Society of Queensland (later The Royal Society of Queensland) on 28 December 1871 (Member No. 78). He became a Life Member by paying five years' subscription and was very quickly elected to the Society's Council on 25 January 1872.

He was elected a Fellow of the Royal Astronomical Society (F.R.A.S.) on 9 February 1872, and of the Royal Society of Tasmania on 8 October that same year for donating, and then having delivered free of charge, two dugong skeletons.

It therefore appears that the establishment of the observatory (completed in late 1871 or early 1872) was concurrent with O'Reilly's rapid development of astronomical and scientific interests, but it is deeply regrettable that he had less than five more years before his final illness.

Despite the lack of good images, drawings or plans, there is a wonderful report in *The Brisbane Courier* of 10 December 1874 and *The Queenslander* of 12 December. (Bear in mind that the transit of Venus had occurred on 9 December, so the interest of the public had definitely, albeit briefly, turned to astronomy.) This report, titled "Our Local Observatory" in both papers, is identical. It is by the correspondent "JOT" whose identity has not been positively established; however, he displayed a good technical knowledge in this and his other articles. He was most likely James Thorpe (1845–1899), who was born in England and emigrated as a child with his family to Brisbane. In the 1870s he was, together with O'Reilly, a member of the Philosophical Society of Queensland. He was also Secretary of the Society so would have been well versed in the science of the day.

FIGURE 16. O'Reilly's Observatory – part of a larger, panoramic cross-river view, 1873.

The section of this report relevant to the Felix Street Observatory, its contents, equipment and use is quoted in full below:

> Captain H. O'Reilly, as he has already made known through the medium of the Philosophical Society, made preparations for the transit of Venus observations at his private observatory in Felix-street, and in response to his cordial invitation, I spent a very pleasant evening there.
>
> Started several years ago on a small scale, his observatory has now outgrown itself, for on entering it I could not but be struck with the large number of instruments, meteorological and astronomical, crowded within two small rooms – a perfect multum in parvo [much in little; a great deal in a small space or in brief – Latin]; for wherever a picture could hang, a curiosity stand, or an instrument be fastened, you may be sure there was one. Water color drawings of the Eclipse Expedition at Eclipse Island, stellar maps, including a picture, on a large scale, of a cluster of colored stars, situated near the Southern Cross, showing stars of orange, yellow, blue, and crimson colous [*sic*] ; a photograph of the moon, taken with the great reflector at the Melbourne Observatory ; native weapons, Chinese compasses (real curiosities these), belonging to an age when our present compass was in its infancy ; a wind gauge, devised by the Government astronomer at Sydney, comprising four revolving cups, which register their velocity by means of a series of dials similar to those of a gas meter. When required for use, the gauge (which can be held in one hand) is held in the wind for three minutes, the time being regulated by an egg-boiler attached to the stand, the number of revolutions during the time is then ascertained, and converted into miles by means of a small printed table compiled for the purpose. The great recommendation of the gauge is its portability. Besides these, standard barometers, wet and dry bulk thermometers, aneroids, hygrometers, sympiesometers, &c., went far to fill up any vacant spaces in the rooms mentioned.
>
> But having tarried too long in the outer room, accompanied by the host I now entered the transit room, an apartment nearly wholly covered by an iron dome, revolving on cannon balls, with a shutter in it opening so as to give a view from the horizon to the zenith of any portion of the heavens desired, the remainder of the building being covered by two flat shutters opening north and south ; under them is situated the transit instrument, the chief in any observatory. This instrument, made by Jones, of Charing Cross, London, has a 2-in. object glass, a focal length of 20in., and is provided with five wires ; direct and diagonal eye-pieces, and a declination circle, which is divided to minutes of arc.
>
> In connection with, and close to the telescope is the sidereal clock, by Cochrane of Brisbane. This clock, which has a mercurial pendulum, has given proofs of being of first-class workmanship, for, during the last two months its average rate, as deduced from observations of the sun with the transit circle, has been only .3 of a second gain daily. This, considering the circumstances under which it is placed, close to a flat roof, and exposed to great variations of temperature, may be considered as exceptionally good.
>
> With the telescope and clock is connected a "chronograph" or 'time-writer', an instrument similar to the ordinary telegraph instrument, and devised to enable the clock to record seconds of time on a fillet of paper by means of electricity. When used in connection with the telescope, the observer, by means of a small telegraphic key held in his hand, records the time when the object observed passes each wire in the telescope, by dots side by side with those made by the clock. In this manner the clock error is ascertained, for, the exact time of the sun's limb passing the meridian being known beforehand, the time when it passed, as given by the clock, is compared with it, and the difference will show the clock error to the hundredth part of a second.
>
> A glance of the row of chronometers sent to be rated by the captains of the various vessels in harbor testifies that they are fully alive to the facilities of this observatory for obtaining the errors of their chronometers.
>
> A very good mean-time clock by the same maker stands in the same room. Both clocks are kept in excellent order by Mr. Given.
>
> The equatorial telescope under the dome is a powerful 4½-inch instrument of 5 feet focal length, by Ross, of London, mounted on a Varey tripod stand fixed on a stone foundation, as are also the clocks and the transit instrument.
>
> The dome being revolved and the shutter opened, Captain O'Reilly obligingly turned the equatorial on to several objects of interest. But I cannot dwell on the scenes unfolded to me of minute specks of

light which turn out in the telescope to be clusters, each made up of myriads of stars, of light cloud-like patches which resolved themselves into calm milky seas of nebulae, seas of glowing gas, baby worlds ; or of stars which, on being tested with this magic crystal, quadruple themselves, appearing as four suns, which, by observations, are found to circle around each other in pairs.

These and other marvels were rapidly shown to me and explained by my host, who shifted the dome, changed the eye-pieces of the telescope, and picked up the various stellar objects with an ease which betokened long familiarity with the science.

His telescope is provided with six eye-pieces of magnifying powers ranging from 65 to 400 diameters ; but very rarely can the highest powers be used, the 'desideratum' [from Latin – the indispensable or desired thing] being a steady atmosphere and a very fine adjustment, to enable them to be used satisfactorily. What an astronomer would call a "good" night is of rare occurrence—about six a year in England, I have heard.

The declination and right ascension circles attached to the instrument are of silver ; it can be readily clamped down in either, and is provided with slow motions for each. The want of a clock-work motion, to enable the observer to follow the course of a star easily and surely, must, I think, be much felt by Captain O'Reilly and his confreres, and especially during the transit of Venus observations. For this event many preparations were made, not the least among which is a moveable arm for holding a sheet of paper at certain distances from the eye-piece. On this sheet is thrown by the telescope a magnified image of the sun or moon, of any diameter required. By this means Venus's track across the sun could be watched at ease, and without putting oneself into any of the many extraordinary attitudes which are almost inseparable from astronomical observations.

The gong of the mean-time clock now struck the hour for retiring, so after taking a glance at an artificial horizon made of dark glass and levelled by means of three screws and a spirit level (thus doing away with the old quicksilver method), and at an instrument with the formidable name of dipleidoscope devised for transit purposes, I shook hands with my kind entertainer, and bade him "good night," thinking, as I went home, that in a few years, and when the commerce of the city has greatly exceeded its present dimensions, the keeping of correct time and the watching of the skies will not be left to private amusement or enterprise in a colony which devotes a tenth part of its expenditure to educational purposes.

JOT (1874 a,b).

At his observatory, O'Reilly also had a large, possibly iron meteorite. In the 21 June 1873 edition of the Sydney publication *The Australian Town and Country Journal*, a reporter who visited the observatory states: "There is also a large meteoric stone, which was seen to fall at Transit Station near Gympie [in South East Queensland]" (Anon., 1873a). However, JOT in December 1874, writing his comprehensive report of an evening visit to the observatory, does not refer to it, despite carefully detailing the contents of the observatory building. This is curious because it was an important exhibit. A possible explanation is that the meteorite, being large and weighty, was kept outside and so not seen by JOT. Alternatively, it may have been removed before the time of his visit. In any event, no further record of it exists.

## TRANSIT OF VENUS, 9 DECEMBER 1874

The transit of Venus on 9 December 1874 had been observed under excellent conditions by O'Reilly, and the report of his observation in *The Queenslander* of 12 December states:

> There was no "Black Drop". The dark edge of Venus was illuminated five minutes before internal contact and that planet came on to the sun, passed over its face, and went off preserving a well-defined round disc. As Venus advanced upon the sun's disc at internal contact at ingress, a thin greenish stream of light was visible between her and the sun's edge, and gradually became brighter, until the planet appeared a complete circle on the sun. The following are observations for Brisbane mean time:—
>
> External contact at ingress .. .. .. .. .. not observed.
> Internal contact at ingress .. .. 0h. 30m. 21s. p.m.
> Middle of contact .. .. .. .. .. .. .. 2h. 14m. 58s. p.m.
> Internal contact at egress.. .. .. .. 4h. 2m. 40s. p.m.
> External contact at egress .. .. 4h. 32m. 10s. p.m.
>
> A neutral tint-shade was used with a power of 115 (Anon., 1874).

The image was also projected upon a specially marked large sheet of cardboard for observatory visitors.

## ACTIVITIES OF THE OBSERVATORY

O'Reilly was clearly familiar with the heavens, but I have found no indication of any specific line of observation or research conducted at the observatory.

In conjunction with astronomy and meteorology, and given his nautical background, O'Reilly tested ship's clocks for accuracy. An accurate ship's clock was essential for navigation because it was necessary to ascertain longitude, and use of an accurate clock was the most practical way at the time. Determining latitude was relatively straightforward. It could be obtained at sea by a sextant, etc., measuring the altitude of objects, the Sun and stars, especially as they transited.

However, determining longitude was traditionally a problem. Because the Earth is spinning on its axis, knowing the distance/angle the observer is around it (longitude) can best be found by knowing the standard time at which the positional observation by sextant or other instrument is made. It is essential to do this because the sky at the same latitude, e.g. Sydney, Perth, Cape Town or Buenos Aires, will look the same at the same local time. So (say) at 7.00 pm, the night sky would be effectively identical in any of these places. But, again as an example, Sydney is some 10 hours or 150 degrees ahead of Greenwich, the standard reference point, so any sextant or other observation referenced to a very accurate clock, with the appropriate correction, will provide accurate positions at sea, because it will allow for this shift in longitude. The rotational movement of the Earth's surface at the equator is close to half a kilometre per second, so the greater the accuracy of the clock (and, of course, the instruments employed), the better the result. So, until the advent of radio time signals, the ship's clock was an extremely important piece of equipment.

## THE OBSERVATORY ON WICKHAM TERRACE, 1881 (PRINCIPALLY A METEOROLOGICAL AND TIME SERVICE)

This observatory came into being upon the sale of the previous observatory and its contents to the Queensland Government in 1880, three years after the death of Henry O'Reilly in 1877. The purchase had been arranged by his son, Charles John O'Reilly (1854–1925). The representations, namely for the Queensland Government to purchase the observatory as a public service, which may have been the initial stimulus for the Government to act, were first mooted at the meeting on 30 November 1876 of the Philosophical Society of Queensland and became a formal approach by them after their 4 January 1877 meeting. By that stage Henry O'Reilly was gravely and terminally ill, and it was hoped that his instruments would be retained in Queensland. Following the Government purchase, the instruments were turned over to Edmund MacDonnell, the Government Meteorological Observer. Therefore, the approval and purpose of the purchase appear principally to have been for the meteorological, and not the astronomical aspect of use. However, use was soon to be made of the transit telescope to keep accurate time, and the 4½-inch refractor would occasionally be used for the demonstration of celestial objects. (Later, a larger and more satisfactory transit instrument would be obtained and used.)

The construction of the observatory at the new site was reported in *The Brisbane Courier* of 14 June 1881. It decried the lack of a means of obtaining correct time in Brisbane and noted that this would be corrected when the observatory was in operation. Then it stated: "The structure which formed Captain O'Reilly's observatory, and which is now being put up on the Wickham-terrace reserve, is certainly not an ornament to the reserve, and complaints are being made that such a small dilapidated-looking building should be erected in so prominent a position in the city." The *Courier* hoped that these arrangements would be only temporary and that a more imposing building would be erected upon one of the principal reserves (Anon., 1881). There was at least one similar criticism, but in much stronger terms, in a letter to the editor published on 3 June about the unsatisfactory materials and appearance of the observatory (B.O.J., 1881).

The observatory was situated on the lower (eastern) side of the triangular block on the south-western corner of the intersection of Wickham Terrace and Edward Street, and quite close to the Edward Street alignment. Figure 17, a view overlooking Brisbane, shows its appearance in the early 1880s.

This image also gives an indication of the general appearance of the original building, though at the Felix Street address it had been built on flatter land. The photograph shows two rooms, one a conventional, fairly steep-roofed room, and the second a domed-roof observatory on the higher side, with a very low-pitched transit slot adjoining, all within the same building footprint. This interpretation is made based on the previous description by JOT printed herein.

The clearest of the photographs taken during the earlier period, when the observatory was located at

Felix Street, is the distant cross-river 1873 photograph, and its internal layout at the end of 1874 is described in the report by JOT. The building was rotated 180 degrees when re-erected on Wickham Terrace in 1881. This is because the low-roof section containing the transit slot, which was on the river (eastern) side in 1873, then appeared on the western (Wickham Terrace) side. (Compare Figures 16 and 17.)

For some years after the establishment of the observatory at the Wickham Terrace site, Sir Augustus Charles Gregory, scientist, explorer, and former Surveyor-General of Queensland, undertook time measurements as a hobby from the observatory and personally constructed apparatus for electrically recording the observations. The provision of time and weather recording were the principal activities.

The next photograph (Figure 18) was taken ca 1900 and shows the weather stations with the observatory in the background. The inset image, from a vantage point high on Wickham Terrace, dates from not long after. Both clearly show a small new transit building with a shallower roofline to house later equipment, which had not yet been constructed in the original early-1880s image but appears in an 1886 image.

The photograph also shows that the building and roof of the section containing the transit slot had been extended and dramatically altered by constructing a steep-pitched roof with a new, steeply sloping transit slot. This transit slot extends from the base of the roof to the ridge line. The records show the replacement of the transit telescope and observatory extension for the telegraph before December 1886. However, 1886 photographs, while showing that the separate transit building had already been constructed, still show the flattish roof of the transit section of the main building; so the steep roof was added later, probably (as seen in yet another photograph) after 1893. Thus, until at least 1893, the general exterior appearance of the building remained as it had been since O'Reilly's time. The new steep transit slot referenced would have been much more satisfactory for larger, longer-focal-length instruments, and reinforces the appearance of three distinct sections in the rectangular building, with the dome being in the centre.

FIGURE 17. Wickham Terrace Observatory, early 1880s.

Figure 18, dated ca 1900, shows the handiwork of Clement L. Wragge (famous for his Vortex rain or hail guns) who was appointed Government Meteorologist in January 1887, resigning in 1903. He is shown here at one of his weather stations. It is recorded in *Australasia Illustrated* that "... under his energetic supervision the observatory is becoming rapidly furnished with meteorological standard instruments, and for daily weather marking, during 1887 a daily weather map was commenced which shows the weather in all the colonies of Australia. The observatory contains also a 4½ inch equatorial instrument by Ross of London, also a transit instrument, clocks, chronographs etc. and it is anticipated that a suitable building will soon be erected for it near the present site on Windmill Hill" (Russell, 1892).

But this was not to be. The observatory continued at this site for many years, gradually becoming more dilapidated due to termites and the lack of maintenance, and the site became less suitable (vibration, smoke) as the city grew. The telescope appears to have been little used for anything other than demonstration, though the transit instrument was employed for timekeeping – using the Sun according to a newspaper report (Anon., 1881), and also as stated by Kitson & McKay (2006): "... Edmund MacDonnell, the Government Meteorological Observer (retired 1887) carried out daily astronomical observations on the Sun to determine the local time, and the gun was fired." But an official report states: "... the determination of Brisbane local time by Star transits at least once per week, the result being communicated to the Electric Telegraph office ..." (Department of Public Lands, 1886). Perhaps both methods were in use.

Instead of the signal gun, other methods were tried to publicly provide a time determination. From the beginning of 1895 (after the arrival of the new Kullberg mean solar clock installed in the observatory the previous May), a permanent arrangement was in place with a 5-foot-diameter black time ball being dropped at 1.00 pm from a pole erected atop the Old Windmill building. (The time ball is stated as being 228 feet above high-water level and 79 feet above local ground level (when hoisted), drop 11 feet (McDowall, 1894).) It did not operate on Sundays and public holidays and was controlled by "an electric signal from a clock at the survey office observatory", namely O'Reilly's old observatory. At that stage, the present existing (Eastern Australian) standard time based on the 150th meridian was adopted.

FIGURE 18. Wickham Terrace weather stations and observatory, ca 1900; inset view from a vantage point high on Wickham Terrace (State Library of Queensland).

[*Comment*: In the absence of the adoption of standard time as at present, Brisbane local time was some 12 minutes in advance, and Sydney time five minutes in advance of that based on the 150th meridian. Therefore, if Sydney local time was transmitted to Brisbane, it would need to be advanced some seven minutes to accurately convert to Brisbane local time.]

By this time, the earlier time guns had been replaced by an old 12-pound Howitzer from Fort Lytton. It was retired, though it had not been in constant use throughout: a newspaper report (Anon., 1891) stated that the time gun had ceased.

Though the observatory building was suitable for a single astronomer, it was proving much too small to function as an official observatory and, as stated, was deteriorating markedly. Dimensions given in 1896, by which time it was already in a very poor state, were: 34′ × 9′6″ (10.4 × 2.9 metres); verandah 4′; gable 11′. So, it was quite a modest structure.

The final image of the observatory (Figure 19) was taken from the lower and Edward Street side. Dated to 1918/1919, the building appears 'run down' and the surrounding yard contains equipment and meteorological installations plus several small, latticed or louvred Stevenson screens on supports. Around the time of this last photograph, the very ramshackle observatory was discontinued. Within five years it was no longer on site, apparently having been demolished. It appears that meridian timekeeping transit observations were virtually the only astronomical work in which the Government had any interest. In the Queensland Surveyor-General's report for the year 1920, it states:

> OBSERVING STATION
>
> 50. The erection of the new Trades Hall at the intersection of Edward and Turbot Streets having rendered the site of the existing observatory quite unsuitable for meridian observations, it became necessary to make provisions for carrying on the time service. [A new station was then established atop the new Government Insurance Building, corner George and Elizabeth Streets.]
>
> 53. A small room is now being constructed to house the transit instrument and clocks [at the new premises], and will shortly be ready for occupation. The old site and "hut" in which the astronomical work of the Department has been carried on for so very many years, will then be vacated, and left to the Commonwealth Officers for meteorological purposes only (Spowers, 1920).

So, the meteorology aspect was handed over to the Commonwealth. (Older Brisbane readers will recall that the Brisbane headquarters of the Commonwealth Bureau of Meteorology was subsequently constructed on this site at the corner of Wickham Terrace and Edward Street, and operated for many years before relocating in recent times to the Brisbane Airport.)

FIGURE 19. Wickham Terrace Observatory in 1918/1919 (State Library of Queensland).

## THE ILLNESS AND DEATH OF CAPTAIN HENRY O'REILLY

In April 1866, Henry O'Reilly departed for England for the purpose of having an operation performed because of "a painful disease of one of his eyes, the sight of which had become greatly affected" (Anon., 1877a,b).

He was given quite a send-off, with a banquet in his honour at Braysher's Metropolitan Hotel. The tables were crowded and the demand for tickets outstripped the places available. Many prominent citizens were present, and it was obvious that he was held in considerable esteem (Anon., 1866a).

O'Reilly's diary reveals that in London, after consulting specialists, it was deemed necessary to remove his left eye. The operation was performed on 10 August 1866 by Doctors Basset and Lawson. (This was conducted in the rooms of O'Reilly's lodgings in Harley Street!) After recovering, he visited friends in London and relatives in Dublin, with trips to Liverpool and Paris before returning to Brisbane in 1867.

The diary states that on 13 November 1867, on board the *Yarra Yarra* (Australasian Steam Navigation Company ship on the Sydney–Brisbane run, so presumably bound for Brisbane), "At 2.30pm passed Camden Haven Heads and saw the intermediate shaft, cylinders etc, the only remains of my old favourite the Telegraph, lost I consider by gross negligence ..." (This was correct. The *Telegraph* had been wrecked only five weeks earlier on 9 October 1867. The December 1867 Commission of Enquiry revealed that the captain was not in command but had instructed his chief officer to remain a mile offshore. The captain went to his cabin for about 20 minutes and returned just before impact, appalled to discover they were very close. The chief officer had possibly been induced by passengers to go close to see the remains of the wreck of the *Prince of Wales* (Anon., 1868).)

After returning to Brisbane and resuming his duties, O'Reilly's obituary notes: "... but no permanent benefit resulted therefrom" (from the operation) (Anon., 1877a,b).

Apparently O'Reilly's health did improve, with the condition in remission until possibly 1875 or even early 1876. Despite having only one eye, he was able to successfully continue his employment, purchase and fit out the substantial property Toonarbin on Dornoch Terrace, Hill End (late 1868 onwards), and establish and operate his observatory (1871 onwards).

The obituary continues:

> Ultimately cancer formed on the face near the eye, and for this disease he underwent another operation about ten months ago, which unfortunately was too late to check the spread of the disease. Since then the state of his health grew rapidly worse. He was obliged to retire from his business avocations, and some months ago it was known to the deceased gentleman himself, and amongst his personal friends, that there was no room for hope of his recovery.
>
> During the last few days it became evident that the hour of merciful release from his long and painful illness was rapidly approaching. Yesterday forenoon he was conscious for a little while, and was able to speak with those around him, but it was only the brief revival which so frequently precedes the great final change, and he expired shortly before four o'clock in the afternoon.

Henry George O'Reilly died on 18 February 1877, four days before his 53rd birthday. He was buried at the South Brisbane cemetery.

## THE PUBLIC STANDING OF CAPTAIN HENRY O'REILLY

In the obituary referenced above, it is stated:

> Captain O'Reilly was one of the oldest, if not the oldest servant of the A.S.N. Co. and certainly the Company had none more devoted to its interests, with which he most thoroughly and actively identified himself. The Company has, at various times, been very unpopular in this colony, but that unpopularity never extended to its principal representative. His courtesy to the public never varied, and whether as Captain of the Company's boats or as a medium between his employers and the mercantile community of Brisbane, and his sound judgment and tact has, we make no doubt, often prevented the discontent of the Queensland public with the Company's treatment of the trade of this colony taking a definite shape which might have been far from satisfactory to the great Sydney corporation.

He was well respected, as the reports on his funeral in *The Brisbane Courier* and *The Queenslander* stated:

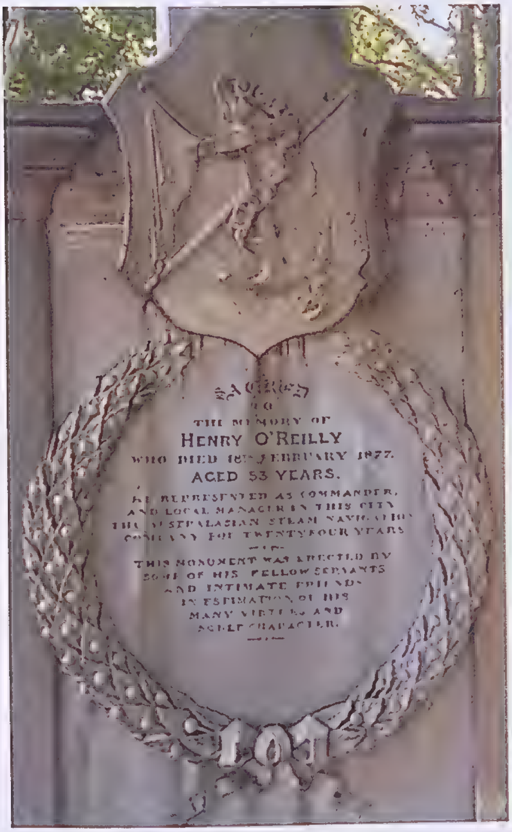
> ... The attendance was one of the largest and most respectable that has ever been witnessed at a funeral in this city, including Sir Maurice

O'Connell, Chief Justice Cockle, several members of both Houses of the Legislature, a number of professional men, nearly all of the principal business men of the city, and many others.

The Rev. T. Jones and R. Creyke officiated at the interment, and the whole proceedings showed how general was the esteem with which the deceased was regarded (Anon., 1877a,b).

His monument, with nautical motifs, is one of the most impressive in the cemetery (see Figure 20).

FIGURE 20. Henry O'Reilly's grave marker.




## AFTERMATH AND LATER USE OF THE INSTRUMENTS

In 1880 following the prompting of the Queensland Philosophical Society to retain the instruments in the colony (30 November 1876, 4 January 1877 meetings), the Government agreed to purchase the astronomical instruments, including a small transit telescope, a chronograph, two clocks and two chronometers, from the estate of Captain Henry O'Reilly. They were transferred to the care of Edmund MacDonnell, the Government Meteorological Observer and deposited in the Trigonometrical Survey hut at Wickham Terrace.

Arthur Page's 1959 address to the Astronomical Society of Queensland includes the following:

> … McDonnell [*sic*] reported to Parliament in 1882: "At the close of the year 1881, the small transit instrument was got in correct position, Sidereal and Mean time clocks put in regulation. Transit observations are frequently taken to correct the sidereal clock, and it is now keeping good time. [This 20-inch-focus transit instrument was replaced in 1884 by a larger 'Troughton and Simms' 32-inch-focus instrument especially purchased for the trigonometrical survey commenced at that time.] The telescope has been the means of many visitors enjoying what cannot be obtained elsewhere in the colony – a personal inspection of the most interesting objects in astronomy and many of the more advanced pupils in both public and private schools have attended the observatory. My best thanks are due to Augustus Charles Gregory, Esq, C.M.G., for the great interest he has taken to, and assistance rendered in connection with the instruments." The appendix to the Auditor General's report 1881 records "3 Nov 1880 – The Postmaster General's purchase of the late Capt. O'Reilly's meteorological instruments £225." Instruments purchased included a small transit instrument, a chronograph, 2 clocks and 2 chronometers, and were moved to a site in Wickham Terrace. [This report fails to state that the purchse included the observatory building as well.] (Page, 1959).

The 4½-inch Ross Equatorial Refractor (pictured in Figure 21) found its way into the Queensland Surveyor General's Department, and around 1926 was loaned to the well-known long-range weather forecaster Inigo Jones, who is shown in this image using it at his observatory at Crohamhurst. The instrument was not returned after his death in 1954, and despite enquiries its whereabouts are unknown. The Queensland Museum of Lands, Mapping and Surveying also holds the sidereal clock built by Cochrane in 1871 for O'Reilly, some of O'Reilly's books and notes on navigation and astronomy, and other instruments dating from this period possibly also having belonged to O'Reilly (Kitson, 2019).

FIGURE 21. O'Reilly's 4½-inch Ross refracting telescope being used by Inigo Jones (Queensland Museum of Lands, Mapping and Surveying).

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## AUTHOR PROFILE

Peter Anderson has been President of the Astronomical Association of Queensland and its predecessors on five occasions since 1966. In addition to active participation in astronomical tourism, especially to observe total solar eclipses, Peter has been a guest lecturer on cruise ships for nine years presenting astronomical subjects. He has also written many articles and is an active contributor in the field. For the last 40 years he has conducted astronomical research from his observatory at The Gap, Brisbane, specialising in the field of lunar and asteroidal occultation of stars. Peter maintains a strong interest in the history of Queensland astronomy.

# CHANGES IN THE FRESHWATER ENVIRONMENTS OF THE AUSTRALIAN LUNGFISH, *NEOCERATODUS FORSTERI*, IN SOUTH-EAST QUEENSLAND, AND IMPLICATIONS FOR THE SURVIVAL OF THE SPECIES

KEMP, A.[1]

This paper assembles evidence collected over several decades to conclude that populations of the Australian lungfish in south-east Queensland are not reproducing sufficiently to guarantee survival of the species in the region. The environment of the Australian lungfish (*Neoceratodus forsteri*) has been altered over the past 50 years. Biodiversity of plants and animals has been lost. Water impoundments without effective fish transfer devices have been built over rivers. Submerged aquatic plants used by lungfish as spawning sites and refuges for the young have been significantly reduced in numbers, and food animals are absent or much less common. Lungfish used to spawn in a number of habitats in rivers and lakes in natural and translocated environments in south-east Queensland, in response to increasing photoperiod in spring. Oviposition events were cyclical, rising from low levels to a peak in successive years and then falling again. High levels of recruitment have, in the past, followed high levels of spawning activity, but recruitment depends on other factors as well. It should be noted that, while the sole trigger for spawning is photoperiod, many factors influence recruitment, such as food availability, refuges for young fish and the effects of predation, as well as the amount and type of food gathered by adult lungfish prior to the spawning season, and whether adults have been able to supply the eggs with appropriate nutrients. Spawning, and the survival of young, are now affected by environmental degradation, with extensive loss of biodiversity in freshwater environments where lungfish live. More to the point, recent attempts to use $^{14}C$ dating to assess the age structure of lungfish populations are flawed and do not support claims that recruitment in lungfish habitats is continuing. Data on spawning included in this paper, and recent reports of recruitment success in several habitats, indicate that this is not the case.

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Keywords: hatchling lungfish, juveniles, spawning, recruitment

## INTRODUCTION

This contribution describes environmental conditions, plant and animal diversity, food and refuge availability, and spawning activity in several habitats in south-east Queensland over a period of 50 years. The Australian lungfish (*Neoceratodus forsteri*) has survived many changes to its habitat in the last 50 years, through droughts and floods, and significant interference from humans, such as intensified droughts and floods, habitat loss, building of water impoundments, environmental contamination, prohibited fishing activities, introductions of exotic fish and illegal exports to Europe and Asia. The lungfish is now isolated in three natural environments in south-east Queensland: the Burnett River (Krefft, 1870); the Mary River (Gunther, 1871); and the Brisbane River (Kemp, 2018; Kemp & Huynen, 2014). These are remnants of an extensive population of several species common in eastern Australian rivers in the Pleistocene (Cavin & Kemp, 2011). The lungfish of the Pine River catchment may have arisen from three translocated fish (O'Connor, 1897) but may also be natural (Kemp & Huynen, 2014). Several translocated populations have survived, in the Condamine, Albert and Coomera Rivers (O'Connor, 1897), and in some man-made reservoirs such as Lake Manchester near Brisbane, although lungfish in these places are not numerous. The lungfish of Enoggera Reservoir, also translocated (O'Connor, 1897), have not had a successful recruitment for many years, since water hyacinth, on which they laid their eggs and amongst which hatchling lungfish could shelter, was removed in 1974, and the remaining adults became very old (Kemp, 2005, 2011). Spawning sites in the Brisbane River were destroyed when Lake Wivenhoe

was created in 1984, and more were damaged during the drought of 2001–2008 (Kemp, 2019), which was followed by severe flooding.

Spawning occurred in freshwater environments in south-east Queensland in most years, in response to increasing photoperiod as always (Kemp, 1984). However, after the construction of Lake Wivenhoe, recruitment was never as regular as the typical annual spawn cycle. Further, juvenile lungfish are not often found in natural environments (Bancroft, 1912, 1918; Illidge, 1893). In recent years both spawning and recruitment have failed despite hopeful statements by some researchers (Fallon et al., 2019). This may be a result of the amount of food available to the adult lungfish (Kemp, 2011, 2014, 2017, 2018, 2019), but continuing environmental degradation and shelter for all stages of the life cycle may also play a part.

The effects of habitat destruction and reduced numbers of food animals on hatchlings and juveniles in large water impoundments in south-east Queensland are already catastrophic. Recruitment of young fish to the adult lungfish population of these reservoirs has ceased in recent years (Kemp, 2011, 2014. 2017, 2019). Lake Wivenhoe and Lake Samsonvale are poor environments for lungfish, with fluctuating water levels, little food for adults or young and few refuges. Nowhere is this more valid than in Lake Wivenhoe, where large numbers of lungfish were trapped when the dam was built.

Recent research (Fallon et al., 2019) has suggested that some young lungfish, about 2–3 years old, are present in the Brisbane River and in the Mary and Burnett Rivers. In fact, the specimens fall within the same range of sizes that have been collected elsewhere at other times (Bancroft, 1912, 1918; Espinoza, pers. comm.), with two exceptions (Longman, 1928; Johnson, pers. comm.), when a number of obviously juvenile fish were found. In the recent study, a small number of fish around 50 cm in length, and a larger number of fish ranging up to a metre in length or slightly over, depending on the catchment, were collected (Fallon et al., 2019). The smallest fish used in that analysis were around 49.5 cm in length, and none, apparently, were younger than two years. However, size of a lungfish relates not always to age, but to the amount of food available as the fish grew (Kemp, 1987). The periods when the fish that were collected could have been spawned included years when the habitats were essentially depauperate, with little food available for large benthic-feeding fish (Kemp, 2014, 2017, 2019), during the years of the drought (2002–2008) and later during times of heavy rain, in 2009–2013, including the massive flooding of 2011. Flooding removes food animals, as well as the places where food animals live, especially when the flooding is prolonged by continual releases of water from reservoirs upstream, as happened after the floods of 2011.

This contribution demonstrates that spawning grounds close to the sites from which the fish used by Fallon et al. (2019) were obtained in the Brisbane River have had no fresh spawn for years. The habitats described in this contribution, from which data have been collected, are: Enoggera Reservoir from 1971–1973, before spawning sites in this reservoir were destroyed; Northbrook in the Brisbane River, from 1977–1981, before Lake Wivenhoe was created; and Lowood and Fernvale, below the wall of Lake Wivenhoe from 1983–2006, before spawning came to an end in these two sites, in 2002 and in 2006, respectively, during the long drought (2001–2008). Conditions of the environment, availability of refuges and food, and spawning activity in Lake Wivenhoe in 2009 and in Lake Samsonvale from 2010–2018 are also described. This information reveals the loss of biodiversity in the river and in water impoundments over the period of the study, and the failure of recruitment in rivers and lakes in south-east Queensland. Possible reasons for the problem are discussed in this paper, and the implications for the survival of the species considered.

## MATERIALS AND METHODS

Spawning by the Australian lungfish is related to increasing photoperiod in spring. In this study, visits to spawning sites began before spawning had started and continued throughout the season until oviposition had ceased. Eggs and embryos of the Australian lungfish were collected from Enoggera Reservoir, an isolated water impoundment in the hills of outer Brisbane (1970–1973), and from Northbrook on the Brisbane River (1977–1981), now part of Lake Wivenhoe, as well as from Lowood (1984–2002) and Fernvale (1983–1992 and 2001–2006), both in the Brisbane River downstream from Lake Wivenhoe. The collections included eggs laid during the drought of 2001–2008, in the course of which time spawning ceased in Fernvale and in Lowood (Kemp, 2019). Eggs were also collected from two sites in Lake Wivenhoe in 2009, and one site in Lake Samsonvale (2010–2018). These two localities are within the large water impoundments created over the Brisbane River

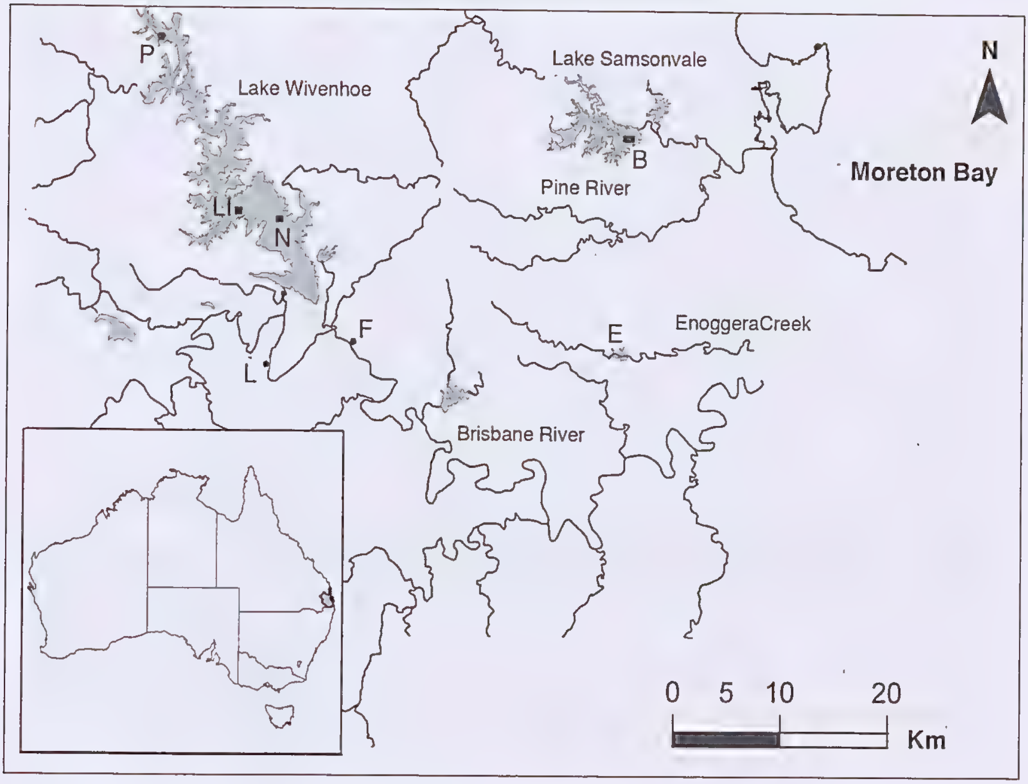
and the North Pine River, respectively. Positions of the different habitats are shown in Figure 1.

Numbers of eggs at different stages of development were assessed and recorded in the laboratory, as were numbers of dead eggs. Details of environmental conditions such as submerged aquatic vegetation, temperature, and animals living in the habitat, some of which are potential food items for lungfish, were noted on every visit to the spawning grounds. Plants and animals found in the spawning sites were identified using the species lists given in Aston (1973), Arthington, et al. (1990) and McKay & Johnson (1990). Diets of adult and juvenile lungfish are described in detail in previous papers (Kemp 1981, 1987, 1996).

*Differentiating Spawning from Recruitment*

Oviposition, or spawning, is not the same as recruitment. There is only one trigger for spawning in lungfish. The process is initiated by rising photoperiod (Kemp, 1984). It has nothing to do with temperature, with the availability of submerged water plants or rootlets, with oxygen levels, with rainfall or water quality, with flowing or stagnant water or with the phases of the moon. Lungfish begin to spawn in early spring, in cool water, and almost always before any significant rainfalls. Phase of the moon has no influence on the onset of spawning or on the production of new eggs during the spawning season. Oxygen levels vary little in most places where lungfish spawn, as does water quality. In a natural river, submerged water plants or rootlets line the shallow water along the banks, and in a water impoundment, there is usually nothing but detritus and filamentous algae, or perhaps ribbonweed and *Nitella*, with or without contaminants such as cattle faeces (Kemp, 2011; Roberts et al., 2014). Water may be flowing or stagnant, and the only movement induced in the shallows of a reservoir is drift caused by wind. Spawning starts and continues in all of these places.

FIGURE 1. Map showing position of habitats in south-east Queensland: (B) Spawning site at the picnic grounds in Lake Samsonvale. (E) Sites in Enoggera Reservoir. (F) Fernvale. (L) Lowood. (LI) Logan's inlet in Lake Wivenhoe. (N) Position of Northbrook, now submerged in Lake Wivenhoe. (P) Paddy's Gully in Lake Wivenhoe.



## RESULTS

### *Enoggera Reservoir*

Enoggera Reservoir is a deep lake, created by building a dam across a valley in the hills of outer Brisbane. There is little shallow water around the reservoir, and most of the banks are too steep to permit the growth of submerged water plants suitable for spawning by lungfish. Remnants of the original Enoggera Creek flow out of the forest upstream of the reservoir and provide an inflow of fresh water in some parts of the reservoir. However, much of the water is effectively stagnant. Along the wall of the reservoir, some submerged aquatic plants grow in the shallows. Enoggera Reservoir never had a natural population of lungfish. Those fish that lived in Enoggera Reservoir were translocated in 1896 (O'Connor, 1897). Enoggera Reservoir and Enoggera Creek are part of the Brisbane River catchment, but the creek joins the main river in the estuary, where the water is always brackish and lungfish cannot survive.

Plants to be found in Enoggera Reservoir from 1971–1973 included the floating introduced water hyacinth (*Eichhornia crassipes*), three species of water lilies (*Nymphaea flava* and *Nymphaea capensis*), both with roots reaching down to the substrate, and free-floating *Nymphoides indica*. Para grass (*Urochloa mutica*), the mud dock (*Rumex bidens*) and hornwort (*Ceratophyllum demersum*) were present in deeper water. Pondweed (*Potamogeton javanicus*) and water thyme (*Hydrilla verticillata*) grew along the shore in shallow areas. Fragments of *H. verticillata* leaves and filaments from the roots of the water hyacinth plants were found in the intestines and faeces of fish from Enoggera (Kemp, 2005). The root filaments of this plant would have been ingested as the fish, which are suctorial feeders, searched submerged hyacinth roots for small animals. This also explains the presence of *H. verticillata* leaves, none of which have been affected by digestive processes.

Animals found in Enoggera Reservoir at the time of the study were sparse. They included a planorbid snail (*Gyraulus meridionalis*), a large air-breathing snail (*Larina strangei*), the water bug *Lethoceras insulanus*, dragonfly nymphs and dragonflies and two species of crustaceans (*Daphnia pulex* and *Paratya australiensis*). The freshwater sponge (*Trochospongilla latouchiana*) also occurred in Enoggera Reservoir. Found in the intestine or faeces of adult lungfish from Enoggera Reservoir were snail shells from *G. meridionalis* and fragments of *P. australiensis* shells, as well as root hairs from water hyacinth plants and leaves of *H. verticillata*. Young lungfish fed on *D. pulex*. The air-breathing snail *L. strangei* is not eaten, nor are the water bugs. The latter are voracious predators of hatchling lungfish.

Until 1974, when the water hyacinth was destroyed by herbicides, lungfish spawned every summer in Enoggera Reservoir, always using the trailing roots of the water hyacinth as sites for the deposition of eggs. Spawning sites in this water impoundment produced only small numbers of eggs (Table 1) and the season was relatively short, beginning in August or September and lasting for about six weeks. Temperatures were moderate, ranging from 18°C early in the season to 23°C later. In most collections, new eggs were found, although eggs of about a week old predominated, and later in the season only late-stage embryos were collected. This site was unusual in that several hatchlings, two in 1971 and three in 1973, were found among the water hyacinth rootlets. Numbers of eggs and embryos reached a peak in 1972. Mortalities of eggs on collection, expressed as a percentage of the total number of eggs found, ranged from 12–23%.

TABLE 1. Numbers of lungfish eggs collected from Enoggera Reservoir from 1971–1973. Stages are: 1, cleavage to 2 days old; 2, blastulae, +3–4 days old; 3, neurulae, +2–3 days old; 4, older neurulae, +4–6 days old; 5, prehatch, +7 days old; 6, perihatch, +10 days old. Columns of numbers refer to stages at collection, not to eggs dying at those stages. The last column refers to deaths as a percentage of the total number of eggs collected.

| Year | Total | Live | Dead | 1 | 2 | 3 | 4 | 5 | 6 | % |
|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | 295 | 226 | 69 | 98 | 34 | 27 | 37 | 11 | 19 | 23% |
| 1972 | 414 | 358 | 56 | 43 | 67 | 55 | 77 | 100 | 16 | 14% |
| 1973 | 173 | 153 | 20 | 21 | 29 | 45 | 38 | 10 | 10 | 12% |

In 1971, 2 hatchlings were found among hyacinth rootlets; and in 1973, 3 hatchlings, in addition to eggs and embryos collected.

Lungfish in Enoggera Reservoir carried out a co-ordinated courtship ritual, involving two fish swimming rapidly at the surface of the water and progressing to the deposition of eggs, one by one, with the fish entwined and in contact with the water hyacinth roots, usually within a few inches of the water surface, but occasionally deeper (Kemp, 1984). Lungfish used water hyacinth in several places, two near the creek where water flowed slowly past the hyacinth roots and one further away with stagnant water. The hyacinth provided secure hiding places for young hatchling lungfish and these were used as habitats by juveniles as well (Longman, 1928). During the spawning season, adult lungfish were often seen rising to the surface of the water to breathe.

*River Localities*

Spawning and recruitment were prolific in many places in the Brisbane River before and after Lake Wivenhoe was created, until biodiversity in the river declined during the drought of 2001–2008. Lungfish spawned every year in the upper Brisbane River above the weir at Mount Crosby and this activity continued for many years. Sites where spawn could be found readily were the river at Northbrook, before Lake Wivenhoe was built, and at Lowood and Fernvale after the lake was completed.

The river at Northbrook (Figure 1) was a rich environment, with clean, flowing water and many species of submerged or floating aquatic plants, including ribbonweed (*Vallisneria spiralis*), water thyme (*H. verticillata*), three species of pondweed (*Potamogeton crispus*, *P. javanicus* and *P. Perfoliatus*), water hyacinth (*E. crassipes*), a species of stonewort (*Nitella*), filamentous algae (mostly *Rhizoclonium*), the hornwort (*C. demersum*) and the water milfoil (*Myriophyllum aquaticum*). The water primrose (*Ludwigia peploides*), the mud dock (*R. bidens*) and the invasive introduced grass *U. mutica* were also present but not in large numbers, as were water lilies (*N. flava*, *N. capensis* and *N. indica*). River bottlebrush (*Callistemon viminalis*), growing along the shores, extended long, filamentous roots into the water, as did some isolated plants of *Lomandra longifolia* growing below the trees. Further upstream, the river flowed over a shallow bay containing many plants of *V. spiralis*. To one side of this area was a pool with dense banks of *H. verticillata*, and on the other side river bottlebrush trees shaded water containing a few plants of *E. crassipes*. Infestations of ferny Azolla (*Azolla pinnata*) occurred occasionally. Deep, clear water flowed past all three sites. Many eggs were found attached to the *V. spiralis* plants, and on the water hyacinth. Eggs were often laid on the *C. viminalis* and *L. longifolia* rootlets, but none on the water thyme.

Insects included dragonflies and the water bug *L. insulanus*. The shrimp *P. australiensis* and prawns (*Macrobrachium australiense*), as well as a common water snail (*Thiara balonnensis*), the basket clam (*Corbicula australis*) and *G. australiensis* (the ram's horn snail) were present in large numbers and provided food for adult lungfish (Kemp, 1987). Scales of small fish such as hardyheads and gudgeons were occasionally found in the faeces and stomach contents of adults. Rotifers, tubificid worms and chironomid larvae, as well as small crustaceae such as *D. pulex*, were present among the submerged macroflora, and would have been eaten by hatchling lungfish. Young lungfish raised in the laboratory eat tubificid worms, chironomid larvae and small crustaceae (Kemp, 1981). Mayfly and dragonfly larvae and a freshwater sponge (*Spongilla alba*) were also to be found at Northbrook. The common freshwater catfish (*Tandanus tandanus*), a large freshwater mussel (*Cucumerunio novaehollandiae*) and the live-bearing snail *L. strangei* occurred in this part of the river. These species of molluscs were not eaten by lungfish. The freshwater leech *Limnobdella australis* also occurred at Northbrook. This part of the river had enormous numbers of potential food items for adults and young lungfish, as well as a range of spawning sites that also provided refuges for young fish.

Water temperatures ranged from 16°C early in the season, in August, to 24°C in December. Water plants were not encrusted with short filamentous algae, and the environment was clean. Lungfish spawned from August to December at Northbrook, using beds of *V. spiralis* in full sun, or the trailing submerged roots of *C. viminalis* and *L. longifolia* in partial or full shade. Occasionally, some eggs were found on water hyacinth rootlets, in partial shade, but not in stands of water thyme. Other plants were not used for spawning. Northbrook sites were productive for five years between 1977 and 1981, before Lake Wivenhoe was filled, and many eggs of all stages were collected (Table 2). Mortality of eggs and embryos from Northbrook, expressed as a percentage of total eggs found, was always 10% or below when they were collected and assessed in the laboratory (Table 2). Most of the eggs were young, and laid within the few days prior to collection. Some late-stage embryos were collected, but no hatchlings, as hiding places within the submerged water plants were plentiful. Adult lungfish were never seen at Northbrook.

TABLE 2. Numbers of lungfish eggs collected from Northbrook sites in the Brisbane River from 1977–1981* (stages and percentages of deaths as in Table 1).

| Year | Total | Live | Dead | 1 | 2 | 3 | 4 | 5 | 6 | % |
|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 147 | 132 | 15 | 102 | 18 | 6 | 6 | 0 | 0 | 10% |
| 1978 | 1080 | 1031 | 49 | 160 | 406 | 289 | 68 | 76 | 32 | 5% |
| 1979 | 742 | 687 | 55 | 181 | 172 | 88 | 132 | 86 | 28 | 7% |
| 1980 | 498 | 477 | 21 | 118 | 71 | 111 | 124 | 47 | 6 | 4% |
| 1981 | 381 | 362 | 19 | 94 | 54 | 77 | 101 | 36 | 0 | 5% |

* No hatchlings.

Clearing of the river banks in preparation for the building of Lake Wivenhoe began in 1981, and the water impoundment was finished in 1984. Filling of the lake removed a productive and valuable environment, not only for lungfish but for many other animals and plants. After the Northbrook site was flooded by the waters of Lake Wivenhoe in 1984 (Figure 1), most of the vegetation and animal life that supported a population of adult and hatchling lungfish previously found in the river in this region disappeared. Lungfish were trapped in the Lake. The Northbrook region, including the archaeological site of Platypus Rockshelter, where lungfish bones dating from 3500 years BP were found (Kemp & Huynen, 2014), is now completely submerged. Within a year of its completion, the shores of Lake Wivenhoe were colonised by massive amounts of filamentous algae.

A major spawning site on the Brisbane River, until 1998, about 5 km downstream of the walls of Lake Wivenhoe, was near the town of Lowood (Figure 1). A sewage outlet from the town emptied into the river about 50 metres above the preferred spawning areas. On one side of the river was a picnic area with public access, with isolated *C. viminalis* trees and a few submerged water plants such as filamentous algae and hornwort, as well as *Pistia stratoides*, the introduced water lettuce. Duckweed (*Lemna* sp.) and ferny Azolla were occasionally present. Water hyacinth was found at Lowood but was not common. On this side of the river, lungfish deposited their eggs on the rootlets of bottlebrush trees and later among masses of *Lyngbya* in the shallows. This site was in full sun. On the other bank, the river was fringed with established *C. viminalis* trees, trailing long rootlets into the water, up to 70 cm deep, in shade for most of the day. These roots were interspersed with plants of *L. longifolia*, and these also had submerged roots. In Lowood, the major site for spawn on the far side of the river, below cattle fields, was the rootlets of *C. viminalis*. Rootlets of *L. longifolia* were also used occasionally. No hatchlings were found in Lowood, but adult lungfish could be seen among the *C. viminalis* rootlets. In other parts of the river downstream, where the banks were in full sun, slimy algae encrusted the submerged rootlets, and lungfish did not spawn on these sites. This algal infestation was absent at Lowood; the rootlets were clean and bathed in flowing water.

Wherever the water was shallow or the weed cover and tree roots were prolific, snails (*T. balonnensis*) and basket clams (*C. australis*) were common and formed a major component of the adult diet (Kemp, 1987). Since adult lungfish are suctorial feeders, masses of sand and filamentous algae were present in the intestine and faeces, but the algae were not digested, and the major food source came from the soft tissues of small molluscs, which feed on the algae. Shells are not digested. Occasionally, the adults ate prawns and shrimps, as well as small fish. *D. pulex*, tubificid worms, chironomid larvae and rotifers were also present in the same places, and these would have provided food for hatchling and juvenile lungfish. The young fish are active carnivores (Kemp, 1981, 1987). Food animals such as *T. balonnensis* and *C. australis* were reduced significantly early in the drought, as were shrimps and prawns. Potential food for hatchling and juvenile lungfish also disappeared at the same time.

Lake Wivenhoe was completed several years before the collections began at Lowood in 1983, and the river below the reservoir was not significantly altered until the long drought of 2001–2008 (Figure 2A). Before 1992, few changes were apparent, despite heavy winter rains in 1988. In 1993, deterioration of the river banks became more obvious and filamentous algae such as *Rhizoclonium* were replaced by masses of *Lyngbya* in shallow, slow-flowing areas, reaching a peak by 2000 after winter floods in 1999. Proliferation of weed plants such as *U. mutica* and *E. crassipes* began.

FIGURE 2. Changes in the Brisbane River at Lowood over the period of the study: (A) The river in 1982. (B) The same part of the river in 2007, near the end of the drought. (C) The Lowood site immediately after the flood of 2011. (D) The Lowood site in 2017. The only constant in this environment is the sewage outlet behind the trees in the distance.

Gastropods and basket clams gradually disappeared and most of the food required by adult lungfish was no longer available.

In recent years, changes to the Lowood site have been fundamental. Towards the end of the drought, enormous quantities of Para Grass (*U. mutica*) infested both sides of the river, eventually obliterating the character of the river (Figure 2B). This infestation was carried away during the floods of 2011, and larger trees on the river bank were also destroyed, as were submerged plants and water hyacinth (Figure 2C). *C. viminalis* trees have survived, with trailing rootlets, but the topography of the Lowood site has been altered. Deep pools have been filled in. Water around the *Callistemon* rootlets is shallower, the rootlets are shorter, and *L. longifolia* plants have gone. Submerged aquatic plants are still absent, as are *Rhizoclonium* and *Cladophora*. The river is significantly altered (Figure 2D) and has not yet recovered its former structure. Lungfish are not known to have spawned in the Lowood site since 2002.

Numbers of eggs collected from Lowood over the period of the study, from 1983 to 2002, varied (Table 3). Spawning in this site began in late August or early September, when water temperatures were around 18°C, and lasted until November or even December in warmer water, up to 25°C. Collecting in this site began in 1983, when numbers of eggs found were moderate, reaching a peak in 1984, falling to low levels in 1987 and 1988 and absent altogether in 1989. Mortalities of eggs on collection, expressed as a percentage of total eggs found from 1983–1986, was low (Table 3). In subsequent years, as conditions in the river began to deteriorate, mortalities were usually higher. A major peak of spawning was recorded in 1993–1994, most probably the last large burst of potential recruitment of lungfish in this part of the river; and much smaller peaks in 1998 and in 2001, when environmental quality had declined significantly in Lowood. Spawning failed for one year in 1999 and ceased entirely in 2002 during the drought. Spawning seasons of 1989 and 1999 with no eggs found often followed high winter rainfall, causing flooding which removed most of the submerged water plants from parts of the sites. However, the

*Callistemon* rootlets on which the lungfish laid most of their eggs were still present. Absence of spawning may have been due to a reduction in food supplies over the months before spawning should have begun.

In 1996, lungfish ignored the *C. viminalis* rootlets and eggs were found only amongst masses of *Lyngbya* in the shallows, in reduced numbers. These eggs were exposed to strong sunlight during the day. It is hardly surprising that egg mortalities reached a peak of 35% during this season. Some embryos from Lowood were approaching the stage of hatching, but no hatchlings were collected here, possibly because hiding places amongst the submerged roots of the *C. viminalis* trees were so readily available. Most collections of eggs in Lowood consisted of young stages, newly laid or up to a few days old, with smaller numbers of late-stage embryos, particularly late in the season.

Spawning ceased in the Lowood localities in 2002, when plant and animal life in the area were significantly reduced. Although *C. viminalis* rootlets were present on one side of the river, all the areas were infested by overgrowths of *U. mutica* and snails and clams were scarce. The major flood of 2011 removed the para grass, but also damaged the structure of the river and the vegetation, as well as the submerged rootlets along the banks. Spawning in this site has not recovered.

Fernvale, about 5 km below the Lowood area (Figure 1), was used for collections in some years, but there were never as many eggs available here as at the Lowood site. The river at Fernvale has a channel of deep, fast-flowing water midstream, filled with long-leaved plants of *V. spiralis*. Adult lungfish could occasionally be seen moving amongst these plants. On one side, the river flowed over a wide, shallow area below *C. viminalis* trees, with patches of *V. spiralis* plants in places. On the opposite side of the river was a site with deeper water, also below *C. viminalis* trees, interspersed by occasional willows (*Salix babylonica*). The shallow area was adjacent to a public picnic area and the opposite side was below fields used for horticulture. Water temperatures at Fernvale were moderate, ranging from 20°C to 24°C.

TABLE 3. Numbers of lungfish eggs collected from Lowood in the Brisbane River from 1983–2002* (stages and percentages of deaths as in Table 1).

| Year | Total | Living | Dead | 1 | 2 | 3 | 4 | 5 | 6 | % |
|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 649 | 621 | 28 | 106 | 248 | 23 | 201 | 31 | 12 | 4% |
| 1984 | 1073 | 1049 | 24 | 201 | 310 | 253 | 212 | 43 | 30 | 2% |
| 1985 | 536 | 521 | 15 | 31 | 201 | 194 | 51 | 33 | 11 | 3% |
| 1986 | 320 | 303 | 17 | 28 | 135 | 61 | 35 | 44 | 0 | 5% |
| 1987 | 192 | 173 | 19 | 129 | 16 | 4 | 20 | 4 | 0 | 11% |
| 1988 | 152 | 131 | 21 | 52 | 31 | 29 | 13 | 6 | 0 | 14% |
| 1990 | 335 | 250 | 85 | 135 | 69 | 8 | 28 | 10 | 0 | 25% |
| 1991 | 111 | 73 | 38 | 50 | 17 | 4 | 1 | 0 | 1 | 34% |
| 1992 | 620 | 523 | 97 | 307 | 111 | 86 | 14 | 0 | 5 | 16% |
| 1993 | 1373 | 1286 | 87 | 603 | 391 | 266 | 19 | 6 | 1 | 6% |
| 1994 | 1741 | 1399 | 342 | 1053 | 75 | 97 | 155 | 12 | 7 | 20% |
| 1995 | 566 | 455 | 111 | 117 | 263 | 39 | 23 | 9 | 4 | 20% |
| 1996 | 267 | 173 | 94 | 88 | 59 | 20 | 4 | 2 | 0 | 35% |
| 1997 | 234 | 183 | 51 | 91 | 35 | 32 | 23 | 1 | 1 | 22% |
| 1998 | 393 | 286 | 107 | 124 | 85 | 59 | 15 | 3 | 0 | 27% |
| 2000 | 120 | 99 | 21 | 40 | 36 | 5 | 8 | 9 | 1 | 17% |
| 2001 | 182 | 112 | 70 | 32 | 63 | 6 | 7 | 1 | 3 | 38% |
| 2002 | 62 | 41 | 21 | 5 | 27 | 7 | 2 | 0 | 0 | 34% |

* 1989, 1999, 2003 and later, no spawning. No hatchlings found.

Collections in Fernvale, downstream of the Lowood site, presented a profile similar to those at Lowood, with varying numbers and levels of embryos dead on collection, compared with the total number of eggs found (Table 4). Mortalities were high late in the drought years as spawning began to fail (Table 4). Spawning at Fernvale, seriously affected in 2004 and 2005, continued for longer than it did in Lowood during the years of the drought, before ceasing in 2006. The last eggs found in Fernvale came from a shallow area covered by water hyacinth, but they were loose on the substrate. In some years, no eggs at all were found in Fernvale, a site which was frequently affected by human activity, such as by people camping on the river bank or the building of a large bridge over the major spawning site in the *V. spiralis* beds. Analysis of the eggs collected in Fernvale during the years of the drought has shown that, although some of these eggs survived to hatch and to become juveniles, the changes in skin differentiation and in skin sense organs, so obvious in hatchlings from reservoir environments, had already begun in hatchlings from Fernvale (Kemp, 2019).

Until 1999 in Fernvale, snails and basket clams were common in the shallow areas and in the deeper water along the shore, among the *C. viminalis* rootlets. During the drought, environmental flows were not maintained and the shallows had no water. Food animals for adult lungfish gradually became scarce, and this may account for the changes in developing hatchlings already apparent during the drought (Kemp, 2019). As in the spawning sites at Lowood, vegetation and animal life to be found at Fernvale were considerably reduced after 2002.

*Lake Wivenhoe and Lake Samsonvale*

The lake environments, where many lungfish in the Brisbane and Pine River catchments now live (Figure 1), have few food animals for a large benthic-feeding fish like the lungfish. Weed plants such as *Rhizoclonium* proliferate and any animals found are frequently represented by a single specimen in a whole season. Water levels fluctuate, especially in spring, and refuge plants and food animals cannot be established along the shores. Food is limited for all age groups. Spawning sites and refuges for young are deficient at best and usually absent. Eggs in this lake are never attached to *V. spiralis*, the only water plant present, but instead laid loose on the substrate, usually in stagnant water.

TABLE 4. Numbers of lungfish eggs collected from Fernvale in the Brisbane River from 1983–1992*, and later from 2001–2006* (stages and percentages of deaths as in Table 1).

| Year | Total | Live | Dead | 1 | 2 | 3 | 4 | 5 | 6 | % |
|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 15 | 12 | 3 | 10 | 2 | 0 | 0 | 0 | 0 | 20% |
| 1984 | 333 | 317 | 16 | 152 | 87 | 41 | 15 | 22 | 0 | 5% |
| 1985 | 240 | 236 | 4 | 138 | 40 | 38 | 14 | 4 | 2 | 2% |
| 1986 | 134 | 127 | 7 | 17 | 29 | 61 | 11 | 9 | 0 | 5% |
| 1987 | 39 | 33 | 6 | 20 | 13 | 0 | 0 | 0 | 0 | 15% |
| 1988 | 42 | 34 | 8 | 0 | 0 | 14 | 9 | 11 | 0 | 19% |
| 1990 | 45 | 39 | 6 | 23 | 13 | 1 | 1 | 1 | 0 | 13% |
| 1991 | 77 | 55 | 22 | 25 | 23 | 5 | 2 | 0 | 0 | 28% |
| 1992 | 45 | 42 | 3 | 0 | 25 | 3 | 12 | 0 | 2 | 7% |
| | | | | | | | | | | |
| 2001 | 71 | 55 | 16 | 29 | 15 | 9 | 0 | 1 | 1 | 22% |
| 2002 | 169 | 131 | 38 | 49 | 34 | 21 | 4 | 23 | 0 | 22% |
| 2003 | 147 | 133 | 14 | 54 | 21 | 15 | 23 | 14 | 6 | 10% |
| 2004 | 269 | 229 | 40 | 131 | 61 | 12 | 25 | 0 | 0 | 15% |
| 2005 | 69 | 48 | 21 | 19 | 18 | 5 | 6 | 0 | 0 | 30% |
| 2006 | 25 | 14 | 11 | 3 | 6 | 3 | 2 | 0 | 0 | 44% |

* 1989, no spawning; 1993–2000, collections from Fernvale discontinued; 2007, spawning ceased. Records of the percentage of dead eggs in Kemp (2019) were calculated as a percentage of living eggs, not of the total number of eggs. No hatchlings found.

Lake Wivenhoe (Figure 1) was completed and filled in 1984. The lake was intended to protect the city of Brisbane from flooding and to provide water. It takes up a large part of the length of the Brisbane River, leaving only about 50 km of unaltered river between the walls of Lake Wivenhoe and Mount Crosby Weir near Brisbane.

The shallows of Lake Wivenhoe, where lungfish spawned in 2009, provided a poor environment. Available spawning sites consisted of dead grass and masses of filamentous algae, interspersed with faeces, the result of cattle being permitted to graze on the shores of the reservoir. Dead leaves and other detritus covered the substrate. Eggs were shed loose into the water which was usually stagnant, although the shallows where the lungfish spawned may sometimes be subject to currents induced by wind. The eggs drifted around in these currents and some were caught in clumps of faeces and algae or in and around stands of dead grass. Others were washed into warm, shallow water by the wind currents close to the shore, where they died rapidly from exposure to the sun. Any water hyacinth present had short roots and was ignored as a spawning site, although it could provide shelter for eggs if close to the shore (Kemp, 2014). Larvae of the water bug *L. insulanus* were numerous and voracious, attacking and eating many newly hatched lungfish. The egg cases in one site (Logan's Inlet) were weak and allowed some young fish to hatch too soon, before they had any protection from predators (Kemp, 2011). Surviving hatchlings may have found shelter among the detritus on the substrate, but they did not develop ciliated cells in the skin and electroreceptors and mechanoreceptors in the skin were deficient in structure, so that the young fish were unable to sense food in the environment (Kemp, 2011, 2014). Observations of hatchlings raised from eggs collected in Lake Wivenhoe confirmed that they could not sense food, even if any were available in the lake. In the laboratory, they were surrounded by live worms, which are usually eaten voraciously, but they ignored them (Kemp, 2011). After the yolk supply was used up, the hatchlings died, including the single hatchling found among the detritus. None of these factors were addressed in a recent publication on the spawning of 2009 in Lake Wivenhoe (Roberts et al., 2014).

Spawning was prolific in Logan's Inlet in 2009 (Figure 1), but the eggs were not particularly healthy, with many dying before they hatched and many more hatching too soon. Young derived from the later spawning in Paddy's Gully (Figure 1) were healthier and survived for longer, but were still unable to feed because their sense organs were not functional (Kemp, 2014). None of the eggs from Paddy's Gully hatched too soon. Skin ciliation was defective in both environments. The massive spawning in Lake Wivenhoe in 2009 (Roberts et al., 2014) was not repeated in 2010, when only a few eggs were found. Nearly half of the eggs collected from Logan's Inlet were already dead, although mortalities on collection were lower in Paddy's Gully (Table 5).

Lake Samsonvale was built over the North Pine River in 1977, to be used as a water supply for parts of Brisbane. The lake is surrounded by dry sclerophyll forest, regrowth of trees on abandoned farmlands. There are no cattle in the catchment and no agriculture or horticulture around the lake, although these activities were carried on in the past. Water temperatures during the spawning season ranged from 18°C to 22°C. Superficially, the spawning site in Lake Samsonvale looks clean and pristine, but below the surface of the water, the lake is depauperate. The only plants present in the critical shallow shore environments are *V. spiralis* and *Nitella*, and the only animals are a few *P. australiensis* and occasional snails and small fish.

The spawning environment in Lake Samsonvale is unstable (Figure 1), with continual fluctuations in the water level depending on water usage and rare spring rainfalls. Eggs are laid loose on the sandy or gravel substrate among the few plants, with no protection, and often washed ashore during even a mild storm. This action may include masses of eggs, which die rapidly of dehydration or exposure to the sun.

Spawning in Lake Samsonvale began in late August and continued until October. Numbers of eggs varied, and were usually low, except for the large numbers found in 2010 and in 2012 (Table 5). After the flood of 2011 no lungfish are known to have spawned in that year, and no eggs were laid in 2017. In 2012, a few hatchlings were found among the water plants, lying on the substrate with no protection. As in Lake Wivenhoe, hatchlings failed to feed because sense organs were defective. Ciliation in the skin was poor as well and the hatchlings could not keep the skin surface clean. Most of the eggs collected from Lake Samsonvale and reared in the laboratory died for the same reasons as the hatchlings from Lake Wivenhoe. Older-stage embryos and hatchlings that were collected from the lake and not subjected to rearing in the laboratory also died.

TABLE 5. Numbers of lungfish eggs collected in Lake Wivenhoe and Lake Samsonvale from 2009 to 2018 (stages and percentages of deaths as in Table 1).

| Year | Total | Live | Dead | 1 | 2 | 3 | 4 | 5 | 6 | % |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009* | 494 | 260 | 234 | 158 | 28 | 5 | 46 | 18 | 5 | 47% |
| 2009† | 233 | 147 | 86 | 140 | 0 | 0 | 7 | 0 | 0 | 36% |
| 2010 | 1294 | 952 | 342 | 868 | 15 | 67 | 2 | 0 | 0 | 26% |
| 2012 | 3153 | 1412 | 1741 | 471 | 533 | 146 | 100 | 49 | 113 | 55% |
| 2013 | 506 | 344 | 162 | 272 | 61 | 10 | 1 | 0 | 0 | 32% |
| 2014 | 564 | 263 | 301 | 229 | 22 | 12 | 0 | 0 | 0 | 53% |
| 2015 | 282 | 224 | 58 | 146 | 27 | 20 | 16 | 13 | 2 | 20% |
| 2016 | 515 | 231 | 284 | 157 | 31 | 11 | 24 | 1 | 7 | 55% |
| 2018 | 45 | 35 | 10 | 35 | 0 | 0 | 0 | 0 | 0 | 22% |

* 2009, Logan's Inlet, in Lake Wivenhoe, one hatchling found.

† 2009, Paddy's Gully, in Lake Wivenhoe, no hatchlings found. All later collections were from Lake Samsonvale. 2011, 2017, no spawning; 2012, 3 hatchlings; 2018, one female spawning, for one week.

*Factors Affecting Oviposition and Recruitment*

There are well-known cycles of spawning, good years with numbers of eggs rising to a peak, followed by years when smaller numbers are produced, and sometimes with no eggs laid at all for a year, as in the Brisbane River in 1989 and 1999, or in Lake Samsonvale in 2011 and 2017. High levels of recruitment have, in the past, followed high levels of spawning activity. Lack of spawning may coincide with the occurrence of a flood in late summer or in winter, as in Lake Samsonvale in 2011, but not every such flood is followed by a cessation of spawning. The prolific spawning events recorded in Lake Wivenhoe in 2009 (Roberts et al., 2014) were followed by little spawning in 2010 (Kemp, 2014). Fluctuations in spawning in the river and in water impoundments may actually be independent of environmental conditions; and reasons are not apparent.

Many additional factors influence recruitment, such as food availability, refuges for young fish, and the effects of predation on eggs and hatchlings. The amount and type of food gathered by adult lungfish prior to the spawning season influence the growth and survival of young lungfish (Kemp, 2011, 2014, 2017, 2019). If the adults have not been able to gather sufficient suitable food, such as snails and clams, they may have not been able to supply the eggs with appropriate nutrients for development (Kemp, 2019).

Recruitment of young fish to the adult population is not as reliable or as frequent as oviposition, and little information about the numbers of young lungfish in a natural habitat is available. In the present study, two young fish were recovered from water hyacinth rootlets in Enoggera Reservoir in 1971 and three in 1973, all recently hatched. A single hatchling of stage 48 was found among the muck and detritus in Lake Wivenhoe in 2009 (Kemp, 2011). Three newly hatched lungfish were collected from Lake Samsonvale in 2012, lying exposed on the gravel substrate among the water plants.

*Recruitment in the Past*

A single hatchling, 2.5 cm long, was found among water plants in the Burnett River, close to spawning sites, during early research into lungfish (Semon, 1898). Juvenile lungfish, 3.1 cm to 30 cm, are not often recorded from a natural environment, although subadult fish, over 30 cm long, are not uncommon (Illidge, 1893; Bancroft, 1912, 1918). Bancroft made intensive efforts to find juveniles and subadult fish in the Burnett River, using nets, lime and dynamite, after years with good spawning events, and collected no juveniles and few subadult fish. Among many sporadic records of a single juvenile or a subadult fish every few years, Longman recorded a number of juveniles from Enoggera Reservoir and later a few isolated juveniles, also from Enoggera Reservoir, in the following years (Longman, 1928). These young fish were found among the roots of water hyacinth plants that had been exposed on the bank by clearing efforts. Some small lungfish have occasionally been found at Mount Crosby pumping station on the Brisbane River, trapped in the water filters (Grigg, 1965). A large number of juveniles were collected

from the Brisbane and Mary Rivers in 1981 and 1982 (Kemp, 1987). None of these records are a result of a deliberate effort to find juvenile lungfish, but were incidental to other research projects or, in one case, to an attempt to clear water hyacinth from Enoggera Reservoir (Longman, 1928).

## DISCUSSION

The Australian lungfish is under threat from many aspects of human activity, notably from conversion of large areas of their natural riverine environments into reservoirs for water conservation where conditions are not ideal for adults or for eggs, embryos and hatchling lungfish (Kemp, 2011, 2014, 2017, 2019), but also from the effects of climate change on the river environments. Two large reservoirs block parts of the Burnett River, numerous barriers, natural and man-made, affect the length of the Mary River, large parts of the freshwater reaches of the Brisbane River catchment have been turned into water impoundments (Figure 1) with no fishways to allow for movements of fish, and even the small North Pine River has half its length covered by Lake Samsonvale. All of these water impoundments are suboptimal environments for lungfish, and the remaining parts of the rivers have lost diversity as well. The numbers of plants and animals in the habitats have declined in recent years, especially those of use to lungfish. The freshwater environment for lungfish in south-east Queensland has been effectively destroyed, with serious consequences for the last remnants of the extant lungfish.

Recruitment has failed in recent years, despite frequent episodes of oviposition. Eggs and embryos collected in the years up to 1998 from Enoggera Reservoir, Northbrook, Fernvale and Lowood were mostly normal, with good rates of survival and development. Many reached juvenile stages old enough to be recruited into the adult population (Kemp 1999, 2011, 2014, 2017). Although Enoggera Reservoir was not a particularly salubrious environment, many lungfish lived there and spawned every spring, at least while they had access to the trailing roots of water hyacinth plants where they could lay their eggs and where young lungfish could hide. Recruitment in Enoggera failed completely when the water hyacinth was cleared, and the adult lungfish in the reservoir became very old (Kemp, 2005).

The environments in river localities were rich, with many plants and animals, in the times before Lake Wivenhoe was built, and in the years immediately after, before the drought of 2001–2008 and the severe flooding that followed the drought. Northbrook was submerged when Lake Wivenhoe was completed, but spawning continued in the remnants of the river, at least for a few years. Conditions in the Brisbane River began to deteriorate in 2000 and spawning ceased in Lowood in 2002 and in Fernvale in 2006. Losses of eggs were high in both of these areas before spawning actually failed. Problems with development of young fish originated in Fernvale in eggs laid under drought conditions (Kemp, 2019) and before the flooding events that began in 2009. Eggs collected from Lake Wivenhoe in 2009 and from Lake Samsonvale after 2010 did not develop sufficiently to be recruited to the adult population in these lakes, because of anomalies in the skin and skin sense organs (Kemp, 2011, 2014, 2017). In 2016, despite the survival of a number of hatchlings to juvenile stages, all of the young fish died, as a result of poor development of the nervous system, lungs and intestine (Kemp, 2019).

The freshwater environment for lungfish in south-east Queensland has been effectively destroyed. Dramatic losses of biodiversity in freshwater environments in south-east Queensland have certainly affected the ability of lungfish to survive and various forms of human intervention have had further profound effects. Loss of spawning in Enoggera Reservoir followed wholesale destruction of water hyacinth plants, exacerbated by ageing in the adult population (Kemp, 2005, 2018). The river environment exemplified by the Northbrook reaches was completely destroyed by the creation of Lake Wivenhoe. Loss of spawning in the river below Lake Wivenhoe, at Lowood and Fernvale, has been more gradual, and a result of environmental degradation, as well as drought and subsequent floods, all reducing food supplies and the numbers of plants and animals of use to lungfish.

The effects of habitat destruction and reduced numbers of food animals on hatchlings and juveniles in large water impoundments in south-east Queensland are already catastrophic. Recruitment of young fish to the adult lungfish population of these reservoirs has ceased in recent years (Kemp, 2011, 2014, 2017, 2019). Lake Wivenhoe and Lake Samsonvale are poor environments for lungfish, with fluctuating water levels, little food for adults or young, and few refuges. Nowhere is this more obvious than in Lake Wivenhoe, where large numbers of lungfish were trapped when the reservoir was built. The Brisbane River is also affected. Spawning grounds in the Brisbane River have had no recorded fresh spawn for years, since the drought reduced the amount of food available to lungfish (Kemp, 2019).

Research on $^{14}C$ content of elasmodin in lungfish scales has suggested that a number of young lungfish, about 2–3 years old, are present in river systems of south-east Queensland (Fallon et al., 2019). There are, however, problems with this research. The original method used to assess the ages of lungfish (James et al., 2010) is not valid, for several reasons (Kemp, 2015; Kemp et al., 2015). The research does not accurately report on the morphology of lungfish scales or the way that scales form and grow (Kemp, 2012, 2015; Kemp et al., 2015). Scales are permanent and consist of layers of mineralised squamulin on the outer surface and layers of elasmodin on the inner surface (Kemp et al., 2015). The ages are assessed using the $^{14}C$ content of the elasmodin (James et al., 2010; Fallon et al., 2015, 2019), a metabolically active, unmineralised collagen matrix which includes large cells on the underside of the scale and essentially a soft tissue laid down in successive layers (Kemp et al., 2015). Under the impression that the elasmodin was bone, James et al. (2010) sampled material from the whole thickness of the elasmodin, deriving not an absolute reading but an average, because they sampled all of the successive layers. The authors found that a peak of activity appeared around the edges of the scale in the most recently formed tissue (James et al., 2010). This has little to do with the absolute age of the fish, and simply reflects metabolic activity in the elasmodin as more layers are produced. Actively secreted collagen contains more of the radioactive carbon present in the fish. It does not reflect age, or suggest that the scale has stopped growing. The later modification of the first technique is equally invalid, because they are still sampling several successive layers of elasmodin in a scale and deriving average values for each point (Fallon et al., 2019). In a living fish, although the layers of elasmodin are permanent, the collagen and the cells contained within it are subject to continual changes, but the $^{14}C$ tests all ignore the possible effects of metabolic activity within the tissue, recycling elements within the collagen. If they had used a small sample from the oldest part of the scale, easily determined because the first formed structure of the scale, the focus, remains clear even in the oldest scales (Kemp, 2012), their results might possibly be considered useful. However, even if analysis of $^{14}C$ in a metabolically active cellular tissue is valid for age determination, the use of several thicknesses of elasmodin in samples taken across each lungfish scale will give only average readings of sequential $^{14}C$ content, not the more reliable absolute values that would be obtained if one thickness were used.

Detailed criticism of the methods and analyses of Fallon and his colleagues is beyond the scope of the present contribution, and is not in fact important, because their method of analysis of the scales is not valid. The original paper was based on three scales taken from the trunk of a fish found dead on the banks of the Burnett River (James et al., 2010), using the whole thickness of the elasmodin for $^{14}C$ analysis. Although the scales were all of the same age and much the same size, the authors expressed their results by using a von Bertalanffy growth function. The same formula was applied to the data in the most recent paper, but the values found do not appear to fit a predicted von Bertalanffy curve at all (Fallon et al., 2019). The $^{14}C$ data from all three rivers are scattered around a slightly curved line (Fallon et al., 2019, Figure 9) despite the wide difference in the purported ages and sizes of the fish used in the research. There must be large differences between fish of 50 cm in length and a few years of age, and fish over a metre in length and around 70 years old, but this is not reflected in the figures shown.

The authors provide no data on the carbon residence time of the land surrounding the environments from which their samples came (Olley, 2010; Kemp et al., 2015), despite sampling $^{14}C$ from *Corbicula australis*, one of the molluscs that lungfish use for food, and concluding that the carbon in the molluscs was not "old carbon", so the carbon in the lungfish was not "old" either. Analysis of some living molluscs during the apparent considerable lifespan of their oldest fish does not provide sufficient data on the carbon residence time of the surrounding land, because the molluscs are not long-lived. Variation in the carbon residence time of all of the land surrounding the collection sites, not considered by the authors, would add an unknown quantity to any reading of $^{14}C$ in the lungfish scales (Olley, 2010). The work reported by this group purports to demonstrate that the riverine habitats of the lungfish are in good condition, and that lungfish populations are thriving, when this conclusion cannot be supported by an examination of the river and by assessment of the spawning activities of the lungfish in any of their current habitats, or by the actual recruitment of lungfish in the rivers and lakes. The methods used by James et al. (2010) and Fallon et al. (2019) to age lungfish scales based on $^{14}C$ present in elasmodin are not valid. Early statements of the paucity of juvenile lungfish (Illidge, 1893; Bancroft, 1912, 1918) are likely to be correct, and the species survives, not because of regular recruitment, but because the adults are long-lived.

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## AUTHOR PROFILE

Anne Kemp was educated in Scotland (Edinburgh University) and has spent most of her adult life in Queensland. She has worked with the Australian lungfish since 1969, mostly on the development of the embryos, hatchlings and juveniles, as well as descriptions of the scales and the dentition of lungfish.

# REVISITING INSCRIPTIONS ON THE INVESTIGATOR TREE ON SWEERS ISLAND, GULF OF CARPENTARIA

COLLINS, S. J.[1], MATE, G.[2,1] & ULM, S.[1,3]

The Investigator Tree, so named after Matthew Flinders' ship HMS *Investigator,* is an inscribed tree currently on display in the Queensland Museum. Before being accessioned into the Queensland Museum's collection in 1889, the Investigator Tree grew on the western shore of Sweers Island in the southern Gulf of Carpentaria. The tree's "Investigator" inscription, attributed to Flinders (1802), provided the catalyst for future and varied forms of European inscription making on Sweers Island, including a contentious additional "Investigator" inscription on the Investigator Tree carved by Thomas Baines in 1856. Previous researchers have speculated that Baines' second "Investigator" inscription has caused the faded original "Investigator" inscription to be misinterpreted as either a Chinese or Dutch inscription predating Flinders' visit to Sweers Island.

For the first time, this study undertakes a physical examination of all markings on the Investigator Tree, including a second portion of the tree located at the Queensland Museum since 2009. In combination with a review of the archival and historical record, findings provide alternative interpretations regarding the (28) inscriptions to address outstanding questions. Archival documents demonstrate that there were at least three inscribed trees on Sweers Island. This paper also revisits the possibility of there once being pre-Flinders inscriptions on the Investigator Tree.

Keywords: Investigator Tree, inscriptions, graffiti, Matthew Flinders, Sweers Island, HMS *Beagle*

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## INTRODUCTION

Australian inscription studies highlight the diversity of inscription making in different temporal and spatial settings across various social, cultural and historical contexts (Frederick & Clarke, 2014, p. 55). Much of the recent literature is situated within institutional settings such as schools/orphanages (Jones, 2018), quarantine stations (e.g. Clarke et al., 2010; Clarke & Frederick, 2012, 2016; Bashford et al., 2016), prisons (e.g. Agutter, 2014; Romano, 2015), sites associated with convict incarceration and transportation (e.g. Casella, 2014), or contemporary graffiti found in urban (e.g. Frederick, 2009; Crisp et al., 2014), semi-urban (Frederick, 2014) or Aboriginal community settings (e.g. Ralph, 2012; Ralph & Smith, 2014). Remote settings also provide locations for graffiti/inscription making (e.g. Delaney, 1990; Winchester et al., 1996; Lowe, 1998; Ralph, 2012; Brady et al., 2013; Fyfe & Brady, 2014; Lewis, 2014). In addition, there is growing scholarship in inscription studies relating to maritime activity in Australia (Delaney, 1990; Clarke et al., 2010; Taçon & Kay, 2013; Van Duivenvoorde et al., 2013; Fyfe & Brady, 2014).

In the maritime exploration setting, inscriptions can act as "postal messages" (Van Duivenvoorde et al., 2013, p. 57). Inscriptions can be analogous to an inscriber marking human presence; or, in the context of maritime exploration, literal markers in the landscape when placed on prominent trees, stone pillars or wooden crosses. As literal markers, they act as communication devices messaging safe passage and represent a ritual activity of the ship/crew collective (Wickens & Lowe, 2008, p. 7; Fyfe & Brady, 2014, p. 66; see also Mostert, 1986; Schoonees, 1991). Leaving markers in the landscape was a centuries-old practice begun by Portuguese sailors (Wickens & Lowe, 2008, pp. 6, 31; Van Duivenvoorde et al., 2013, p. 57) to assert their nation's territorial claims (Van Duivenvoorde et al., 2013, p. 57). This practice of leaving a marker in the landscape was continued

by the early British maritime explorers and settlers of northern Australia, as evidenced by the Investigator Tree discussed here, as well as the Mermaid Tree (Wickens & Lowe, 2008, pp. 41–42), the Gregory Trees (Martin, 2013; Lewis, 2014), the Leichardt Tree (Martin, 2013), the Landsborough Tree (Martin, 2013) and other inscribed trees across northern Australia.

The Investigator Tree, so named because of its "Investigator" inscription, was originally referred to as "Flinders' Tree" by early observers, because of its association with the navigator Matthew Flinders (Baines, 1857, p. 15). Commander John Lort Stokes first recorded the Flinders-related inscription during his visit to Sweers Island in 1841 aboard HMS *Beagle* (1846, pp. 270–271). The Investigator Tree's many subsequent inscriptions chronicle visits to Sweers Island by nineteenth-century maritime and land explorers from 1802–1866, with its "Investigator" inscription representing one of the earliest European maritime inscriptions in Australia. As an archaeological artefact, the Investigator Tree is a rare survivor of the harsh tropical environment of northern Australia, and a testament to the relatively sparse early European engagements in the region.

Modern scholarship on the Investigator Tree and its inscriptions is represented by contributions by Saenger & Stubbs (1994) and Stubbs & Saenger (1996), who contextualised the tree and presented a range of archival evidence regarding contemporary reports of inscriptions on the tree and their interpretation of these reports. In their second paper they test claims of the presence of pre-Flinders inscriptions on the Investigator Tree. Both papers argue that the original, "barely legible", "Investigator" inscription, when compared to Thomas Baines' later second "Investigator" inscription, led to the misinterpretation of the original inscription by nineteenth-century observers as either Chinese writing (Saenger & Stubbs, 1994, pp. 68, 75; Stubbs & Saenger, 1996, pp. 94, 102, 105) or as a Dutch inscription (Saenger & Stubbs, 1994, p. 76; Stubbs & Saenger, 1996, pp. 94, 101, 102, 105).

Our approach to examining the inscriptions attributed to the Investigator Tree includes a comprehensive review of the archival record, as well as a physical inspection, making a detailed recording of the inscriptions and historical alterations made to two extant portions of the Investigator Tree now located at the Queensland Museum (Portion 1 and Portion 2). Detailed physical recording of the two extant portions of the Investigator Tree has not previously been undertaken. By undertaking this exercise, we demonstrate how the artefactual record informs the historical archive and vice versa. We also acknowledge the power of association that instigated repeated inscribing over time. Subsequent inscription makers left marks of self-expression to assert their presence, identity or survival, in deference to Flinders' "Investigator" inscription. By doing so, they cemented their historical present into the fabric of the Investigator Tree, while also writing themselves into the future.

## SITE DESCRIPTION AND SETTING

Sweers Island is the second largest and easternmost of the South Wellesley Islands in the southern Gulf of Carpentaria; it is approximately 8 km long and up to 2 km wide (Figure 1). It is one of several islands in the archipelago comprising the landscapes and seascapes of the Kaiadilt people. Archaeological research establishes Kaiadilt occupation in the South Wellesleys from at least 3500 years ago (Memmott et al., 2016, p. 110).

The exact original location of the Investigator Tree on Sweers Island is uncertain. However, John Lort Stokes named the point on the western side of Sweers Island "Point Inscription" because of its proximity to the Investigator Tree (Stokes, 1846, p. 270). Furthermore, Stokes (1846, p. 270) and Baines (1856–1857) record the Investigator Tree being near a well that was dug at the time of Flinders' visit to Sweers Island in 1802, which was situated about half a mile (1.6 km) east of the point. Thus, the Investigator Tree and Flinders' well were situated near the main entry/exit point to Sweers Island. This entry/exit point was facilitated by the deep anchorage of Investigator Road between Bentinck Island and Sweers Island. In 1867, Benjamin J. Gulliver recorded that the Investigator Tree "stood near the beach, and leaning towards the sea, so close in fact that at high tide a boat could be made fast to it in the ordinary manner" (Anon., 1889e).

George Phillips' 1866 surveys of Point Inscription (Figure 2) and the township of Carnarvon on Sweers Island (Figure 3) document the Investigator Tree's original location (Phillips, 1866–1868; Survey Plan C1351, Department of Natural Resources, Mines and Energy, Queensland). In 1988, as part of Australia's bicentennial celebrations, a memorial stone and a new tree were placed to commemorate the position of the original Investigator Tree on Sweers Island; however, some commentators question the accuracy of their placement (T. Battle, pers. comm., 2017).

FIGURE 1. The South Wellesley Islands, Gulf of Carpentaria (after Ulm et al., 2010, p. 40).

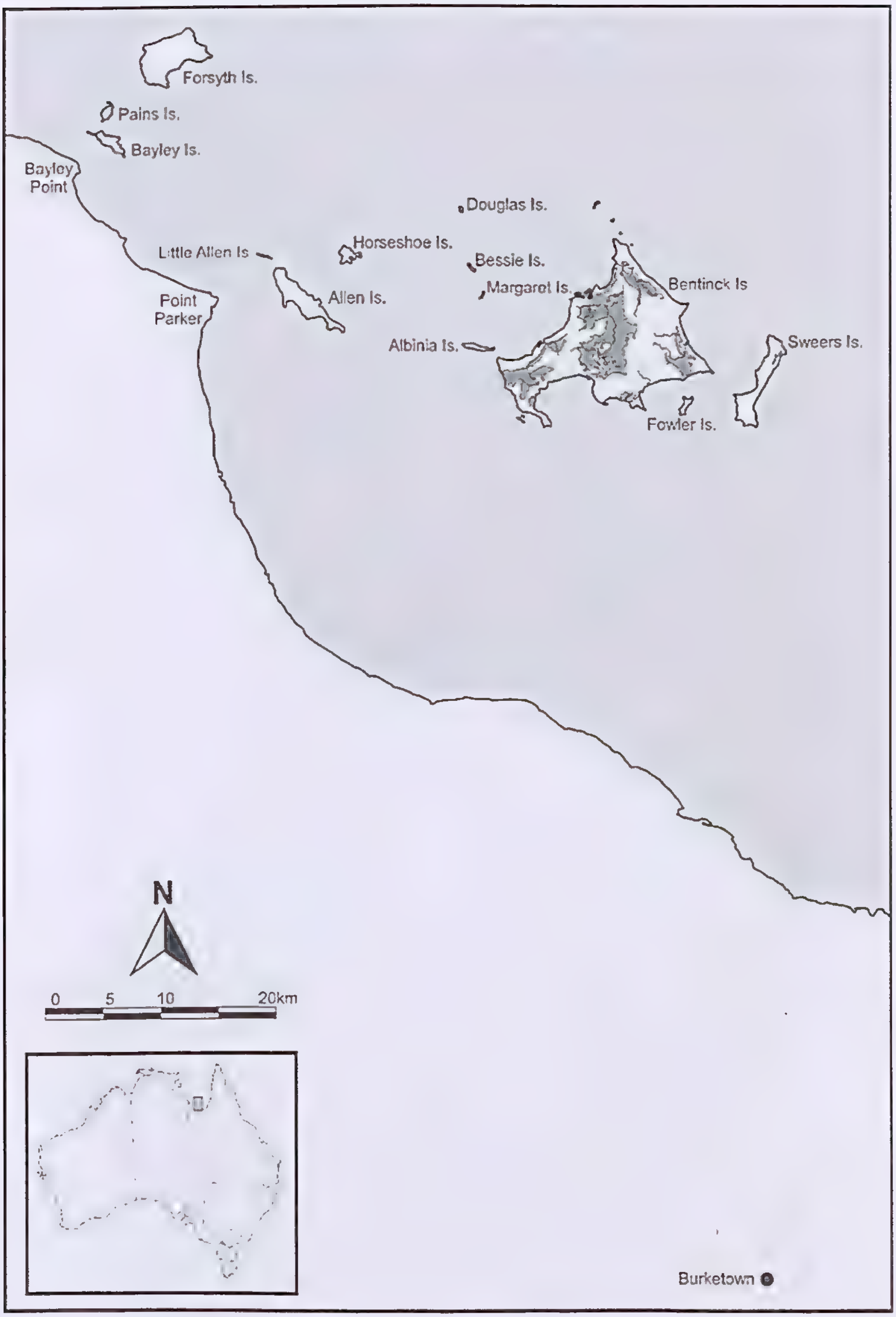


FIGURE 2. Phillips' survey of Point Inscription in 1866, showing the location of the Investigator Tree and the first government buildings on Sweers Island (Phillips, 1866–1868) (Courtesy Royal Historical Society of Queensland).

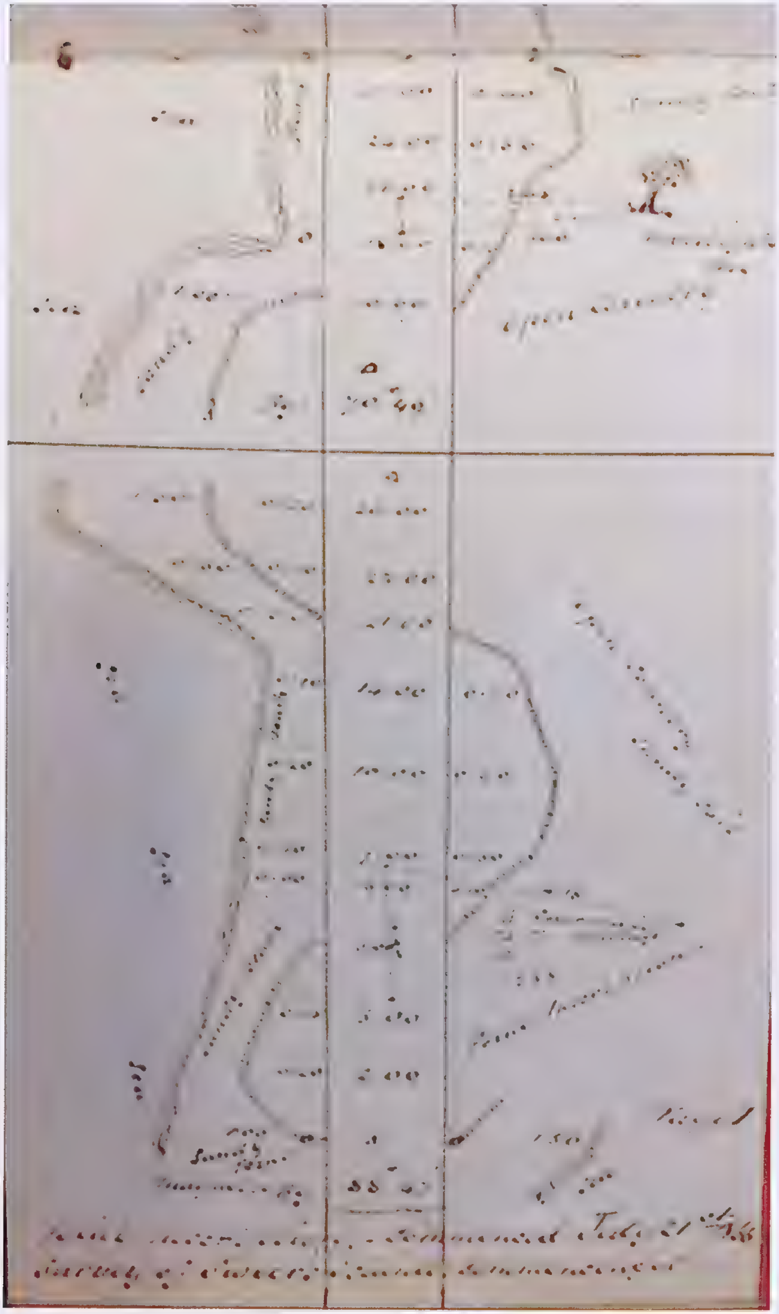
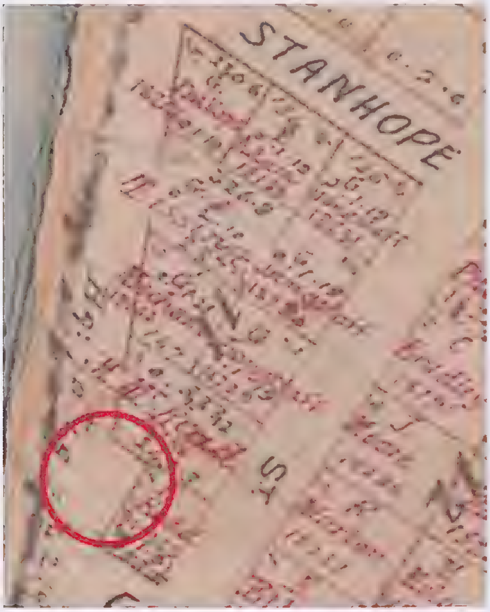


FIGURE 3. Excerpt of Phillips' 1866 map of the Carnarvon township. The space excised out of Allotment 1, Section 11 (circled), is described on the map as the area where the Investigator Tree stood (see Figure 15) (Survey Plan C1351, Department of Natural Resources, Mines and Energy, Queensland).




## BACKGROUND

The ancestors of the Kaiadilt people colonised the South Wellesley Islands at least several millennia before the Macassans, Dutch and British sailed into the Gulf of Carpentaria from the seventeenth century onwards. In 1802 Flinders arrived on the HMS *Investigator* as part of his hydrological survey of Australia's northern coastline and the first circumnavigation of the Australian continent. Flinders' arrival in the Gulf of Carpentaria marked the beginning of British exploration interests in the region, which continued for much of the nineteenth century. Those on board the *Investigator* are believed to have been the first Europeans to land at Sweers Island. Two weeks (17 November to 1 December 1802) were spent in the vicinity of and on Sweers Island so that urgent repairs could be made to the *Investigator* (Flinders, 1814, pp. 135–151). The "Investigator" inscription, named after Flinders' ship and believed to have been inscribed at this time, provided the catalyst for future and varied forms of European inscription making on Sweers Island by subsequent visitors, as well as settlers during the island's short-lived European settlement period, during which the Carnarvon township was established.

## OBSERVERS AND INSCRIBERS OF THE INVESTIGATOR TREE INSCRIPTIONS – HISTORICAL NARRATIVE

The inscriptions on the Investigator Tree have been historically recorded by observers since Commander Stokes' first observation in 1841 until Dr Walter Edmund Roth's visit to Sweers Island in 1901. Inscriptions into the tree's surface were inscribed from 1802 to at least 1866. Recorded observations of Flinders' "Investigator" inscription dominate the archival record, while the inscriptions of less well-known ships, people and expeditions are less frequently cited. The declaration or otherwise of certain inscriptions in the archival record becomes a contested issue surrounding the validity of some observers' claims, in particular the claims by Palmer (1903), Pennefather (1880) and several 1889 newspaper articles that there were pre-Flinders inscriptions on the Investigator Tree. This point will be returned to below.

### *The First Sighting of the "Investigator" Inscription by Stokes*

Flinders' sojourn at Sweers Island in late 1802 is significant because it is reputedly when the first "Investigator" inscription was carved into a tree that has since become known as the 'Investigator Tree'. "Reputedly" because the existence of the carving only enters the historical record for the first time when Commander John Lort Stokes discovers it on his arrival at Sweers Island aboard HMS *Beagle* in 1841 (Stokes, 1846, pp. 270–271), during his survey of the north Australian coast (Powell, 2010, p. 85). Flinders' journals of his 1801–1803 voyages and his later book *A Voyage to Terra Australis* (1814) are silent about an "Investigator" inscription, as are the journals of several other crew members aboard the *Investigator*: Robert Brown (Naturalist), Peter Good (Gardener) and Samuel Smith (Sailor) (Brown, 1802; Flinders, 1814; Good, 1981; Smith, 1801–1803). The absence of any mention of the "Investigator" carving by any of the journalists aboard the *Investigator* sparked debate concerning authenticity within the Queensland branch of the Royal Geographical Society of Australasia, in 1901, when Walter E. Roth unsuccessfully tried to illicit interest in a memorial to mark the Flinders centenary at Sweers Island (Roth, 1901). However, the routine practice of marking a tree may not have warranted a mention by the *Investigator* crew members.

During the *Beagle*'s stay at Sweers Island, "Beagle" and "1841" were carved into the tree on the opposite side of the trunk to the "Investigator" inscription (Stokes, 1846, p. 271). Stokes (1846, pp. 270–271) recorded that: "[i]t was our good fortune to find at last some traces of the Investigator's voyage, which at once invested the place with all the charms of association, and gave it an interest in our eyes that words can ill express". This sentiment would be mirrored by subsequent inscribers keen to associate their names with the Flinders inscription.

*The North Australia Expedition (NAE) and Search Party, 1856*

The frequency of European maritime visitors to Sweers Island increased after the *Beagle*'s visit, likely due to an increase in seaborne traffic in the area that included relief ships to Port Essington, exploration parties, search parties and their support vessels. The first of these was a search party led by Lieutenant William Chimmo aboard the *Torch* tasked with searching for Gregory's North Australia Expedition (NAE) amid concerns for their safety (Chimmo, 1857). The *Torch* arrived at Sweers Island on 30 July 1856. Chimmo records:

> We all assembled beneath THE TREE which still plainly bore the inscriptions of the "Investigator and Beagle;" ... The Torch's name was not added, for if all did the same the original would soon be obliterated, which I hold to be sacrilegious, considering that the original and the originator stand alone as long as wind and weather will permit (Chimmo, 1857, p. 320) (punctuation as in original).

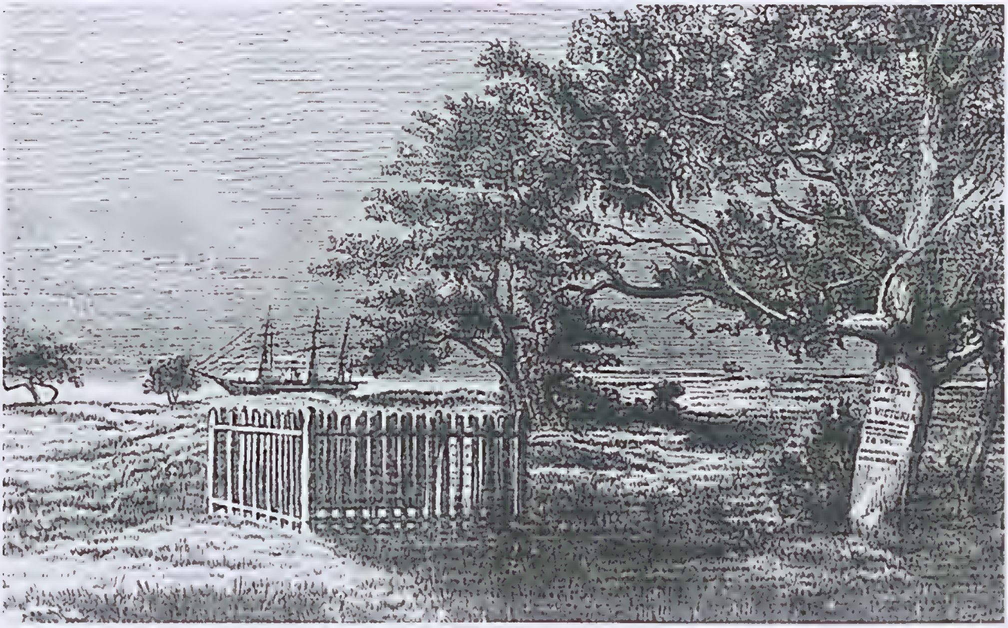
Unbeknownst to Chimmo, the Gregory party had split in two a month earlier: an overland and a seaborne party. The land party, led by A. C. Gregory, left the Victoria River area bound for the Gulf of Carpentaria where they intended to meet up with the seaborne contingent, after the latter first sailed to Coepang for provisions (Baines, 1857, p. 8). At Coepang the *Tom Tough* was replaced with the *Messenger* (Baines, 1857, p. 9). On arriving at the Gulf of Carpentaria, the seaborne party, led by Thomas Baines, realised they had missed their rendezvous with Gregory at the Albert River, and so landed on Sweers Island on 18 November (Baines, 1857, p. 14).

Baines (1856–1857) recorded that "nearly all the men ... carved their names on some smaller trunks of the Investigator's Tree and one invading the Main stem had made some unintelligible cuts two or three of which came across the name of the Investigator". Because the original "Investigator" was "barely legible", and in deference to "this relic of the Adventurous old Navigator", Baines inscribed a second rendering of the word 'Investigator' below the original "Investigator" inscription (Baines, 1856–1857). Baines also inscribed the expedition's mark and date, "NAE NOV 20 1856", while the Captain of the *Messenger*, Robert Devine, inscribed his name and his ship's name (Baines, 1856–1867).

*Victoria Exploration Expedition, 1861*

The Investigator Tree was becoming a signpost to subsequent visitors of past arrivals at Sweers Island, a practice that continued with William Landsborough's Victoria Exploration Expedition in 1861 that was tasked to search for the missing explorers Burke and Wills (Laurie, 1866, p. 17). The *Firefly* and supply vessel HMCS *Victoria* transferred Landsborough's search party and ships' crews north into the Gulf of Carpentaria where two support vessels, *Native Lass* and *Gratia*, awaited them (Norman, 1861–1862, p. 14; Bourne, 1862, p. 11). A contingent of the expedition was stationed at Sweers Island staffing the stores depot for almost four months, 1861–1862 (Norman, 1861–1862). During this expedition's visit to Sweers Island, four people recorded their observations of tree inscriptions: Landsborough records "Investigator 1802" and "Messenger" (Landsborough, 1862, 1866–1871; Laurie, 1866, p. 10); Captain William Norman records "Investigator" and "Beagle" (Norman, 1862, p. 14); George Bourne records "Investigator 1802" and notes that "other names" are also inscribed (Bourne, 1862, p. 11); and, on a nearby tree, Diedrich Henne records witnessing the recently inscribed funerary text of James Frost, the *Victoria*'s Gunner, who died from an accidental self-inflicted gunshot wound (Henne, 1861–1862) (Figure 4). The Frost funerary text inscription can thus be ascribed to another tree, not the Investigator Tree, and was a repeat of Frost's gravestone inscription (Henne, 1861–1862). Frost accidently shot himself while reaching for a loaded gun on 26 December 1861 (Henne, 1861–1862; Norman, 1861–1862, p. 7; Bourne, 1862; Landsborough, 1862). Frost died and was buried on 31 December 1861 – the first recorded European death and burial on Sweers Island (Henne, 1861–1862). A gravestone marks his grave (still *in situ*); however, the inscribed tree recording his funerary text no longer exists.

FIGURE 4. George Gordon McCrae's engraving, after F. O. Handfield's (mate aboard *Victoria*) sketch, of James Frost's grave with the *Victoria* in the background and the funerary text on a nearby tree, as described by eyewitness Diedrich Henne in his 1861–1862 diary (Anon., 1862).



*Evacuation from Burketown to Sweers Island, 1866*

Historically, Burketown and Sweers Island became inextricably linked when a severe outbreak of Gulf Fever occurred at Burketown in 1866. In the same year, Landsborough returned to the Gulf of Carpentaria as the newly appointed Police Magistrate for the District of Burke. As the most senior Queensland Government representative in the area, Landsborough evaluated the extent of the Gulf Fever outbreak at Burketown and decided to evacuate Burketown's residents to Sweers Island (Landsborough, 1866–1871). This emergency relocation was the founding moment of the Carnarvon township on Sweers Island. Two members of the evacuation party recorded their observations of inscriptions on the Investigator Tree: Landsborough, who also added the "W. Landsborough 1866" inscription (Landsborough, 1866–1871), and John Graham MacDonald who provides the first substantial list of inscriptions: "Investigator 1802", "Beagle 1841", "NAE November 20$^{TH}$ 1856", "The Expedition 1861", "Karl Teats 1856", "L.H.XXS. 1861", "W. Solby", "J. Martin" and "J. Austin" (Anon., 1907). MacDonald's list of inscriptions and his sketch of the Investigator Tree (Figure 5) are said to have originally come from MacDonald's 1866 sketch book (Anon., 1907).

*S.S. Eagle, 1867*

The following year, S.S. *Eagle*, captained by Francis Cadell en route to the Northern Territory, arrived at Sweers Island (Robison, 1867–1868; Anon., 1889e). Aboard the *Eagle* were Francis Napier and Benjamin J. Gulliver, who recorded their observations of the Investigator Tree inscriptions. Napier records seeing "Investigator 1802" and "Stokes", as well as the names of "other explorers" (Napier, 1876, pp. 62–63). However, Gulliver, aboard the *Eagle* as Botanical Collector by arrangement of the director of the Melbourne Botanic Gardens, Baron von Mueller, provides a more substantial list of inscriptions that were "distinctly visible" (Anon., 1889e). Gulliver's list of inscriptions on what he terms the "Explorer's Tree" includes: "Flinders Investigator 1802", "Beagle 1841", "NAE Nov 20 1856", "The Expedition 1861", "Karl Teats 1856", "W. Landsborough 1866", "L. H. ***S. 1861", "W. Solby (with two triangles)", "W. J. Hay", "W. C. A. Miles", "W. S. Howell", "A. H. T. 1866", "D. C. Clouston 1866", "J. Martin 1861" and

FIGURE 5. Mr B. Barker's reproduction of John G. MacDonald's original 1866 sketch of the Investigator Tree. Barker has added Carnarvon resident George Longstaff's house to the image (Anon., 1907).

"A. Austin 1861" (Anon., 1889e). Gulliver is uniquely placed amongst observers of the Investigator Tree because he not only records his observations of the tree while it was at Sweers Island, but he also records his observations of the tree when he visits it at the Brisbane Museum (now Queensland Museum) in October 1889 (Anon., 1889e). Although Napier's list of inscriptions is much shorter than Gulliver's, he is the only one of the two to mention a Stokes inscription. This anomaly could indicate that the Stokes inscription was on a different tree.

The difference in the degree of detail between Napier's and Gulliver's observations is representative of similar recording disparities between the observers of the Investigator Tree inscriptions throughout the archival record. It is also interesting to note that many key figures in the Sweers Island story of the nineteenth century omit mentioning the Investigator Tree inscriptions altogether. For instance, George Phillips (1918–1921) and Ernest Henry (1857–1884) both provide eyewitness accounts of the evacuation period from Burketown to Sweers Island in 1866 when they both relocated to Sweers Island, but they do not mention the Investigator Tree's inscriptions; nor do S.S. *Eagle*'s Captain Francis Cadell or carpenter Dugal Robison in 1867. Given Phillips' extended periods of time on Sweers Island during 1866–1867 while surveying the Carnarvon Township, it is curious that Phillips does not list the Investigator Tree's inscriptions. However, Phillips does mark the position of the Investigator Tree on his surveys of Sweers Island (Phillips, 1866–1868; Survey Plan C1351, Department of Natural Resources, Mines and Energy, Queensland) (see Figures 2, 3, 15).

From the archival records, it appears that no additional inscriptions were made to the Investigator Tree after 1866. However, archival documents reveal further observers and recorders of the Investigator Tree inscriptions following the S.S. *Eagle*'s visit in 1867: Captain Charles Pennefather, aboard the *Pearl* in 1880; B. J. Gulliver, in an article in *The Brisbane Courier* (Anon., 1889e), which describes seeing the relocated Investigator Tree at the Brisbane Museum; several 1889 newspaper articles that document the removal of the Investigator Tree from Sweers Island to Brisbane; J. J. Knight (1895), who observed the inscriptions once the Investigator Tree was on display in a museum setting; Dr Walter Edmund Roth, Northern Protector of Aborigines aboard the *Melbidir*, who records the inscriptions remaining on the Investigator Tree stump during his 1901 visit to Sweers Island; and Edward Palmer in his posthumous publication *Early Days in North Queensland* (1903).

Pennefather (1880, p. 1) is the first observer to suggest not only a Dutch inscription on the Investigator Tree, but by implication an inscription predating the Investigator inscription associated with Flinders. He records the inscription "H.M.S. Investigator 1802", "and a still earlier date, supposed to have been carved by the Dutch". In October 1889, Gulliver recalls

visiting the "very old, shrunken, beheaded, [and] curtailed" Investigator Tree in its museum setting where the "Flinders Investigator 1802" and "Beagle 1841" inscriptions were still visible, but the other inscriptions he had previously recorded at Sweers Island in 1867 were "now so far overgrown as to be illegible" (Anon., 1889e). In early 1889 a number of newspaper articles appeared announcing the arrival of the Investigator Tree in Brisbane (e.g. *The Daily Northern Argus* (Anon., 1889c); *The Maryborough Chronicle, Wide Bay and Burnett Advertiser* (Anon., 1889f); *The Morning Bulletin* (Anon., 1889a); *The Queenslander* (Anon., 1889b)). These newspaper articles include a list of the inscriptions to be found on the tree: "1871 Lowy", "1798 and some Chinese characters", "1802 Investigator", "Robert Devine", "1841 Stokes", "1856 Chimmo" and "Norman" (Anon., 1889c). Four of these seven inscriptions are reported by the 1889 newspapers for the first time: "1856 Chimmo", "Norman", "1871 Lowry" and "1798 and some Chinese characters". The originator of this oft-repeated inscription list can be traced to Captain Jones, the Gulf Pilot instrumental in the relocation of the Investigator Tree from Sweers Island to Brisbane (Anon., 1907). It is important to note that this list of inscriptions is the same as Palmer's (1903, p. 26) list published 14 years later, which is significant because until now previous research has attributed the creation of the list to Palmer rather than Jones.

Knight (1895, pp. 5–7) makes his observations once the Investigator Tree is relocated to Brisbane. Knight (1895, 5, 7) records: "Investig", "Investigator", "Beagle 1841" and "T. Devine" (the "T" of the "T. Devine" inscription is the last letter of "Robert" in the "Robert Devine" inscription that Baines (1856–1857) records being inscribed by Captain Robert Devine). However, Knight's (1895, pp. 5, 7) published account of the Investigator Tree and his list of inscriptions is an almost verbatim retelling of an article published in *The Brisbane Courier* (Anon., 1889d). Knight's reliance on *The Brisbane Courier* article for his information possibly explains why, apart from Baines, Knight (1895, pp. 5, 7) and several 1889 newspaper articles (e.g. Anon., 1889d) are the only sources that itemise both "Investigator" inscriptions. Roth's (1901) observations provide the only recording of remaining *in situ* inscriptions of the Investigator Tree. Roth (1901) recorded the "more legible incisions" remaining on the stump of the Investigator Tree: "[o]n the eastern aspect of the butt appears EXPEDITION and 1861 while above it is J. SWAN; along the western side is to be seen P.W. ARMSTRONG, DEC., 1855: upon the main branch is BN within a square border" (Roth, 1901). Roth (1901, p. 1) records Inscription 12 (Table 1) as "P W Armstrong, Dec, 1855". This date has possibly been misread. Instead it should probably be read as "1866", to correlate with the historical record, when Armstrong was a resident and later landowner at Carnarvon township.

Of all the recorders of inscriptions, Palmer appears to be the only one who was not an eyewitness. Historical research cannot place him on Sweers Island, but Palmer did become acquainted with Landsborough and Phillips in April 1866 during one of Palmer's regular visits to Burketown as owner of Canobie Station (Landsborough, 1866–1871). Palmer's list includes: "Lowy 1781", "1798 with some Chinese characters", "Investigator 1802", "Stokes 1841", "Robert Devine", "Chimmo 1856" and "Norman" (Palmer, 1903, p. 26). As stated earlier, Palmer's (1903, p. 26) list is a repetition of a list of inscriptions found in several 1889 newspaper articles (e.g. *The Daily Northern Argus* (Anon., 1889c); *The Maryborough Chronicle, Wide Bay and Burnett Advertiser* (Anon., 1889f)). The same inscription list also appears in *The Morning Bulletin* (Anon., 1889a) and *The Queenslander* (Anon., 1889b) except that these latter two papers do not mention the "Robert Devine" inscription. However, the above-listed newspapers all itemise the "1771 Lowry" and "1798 and some Chinese characters" as inscriptions found on the Investigator Tree, thus providing the first recorded mention of Chinese inscriptions on the Investigator Tree. Therefore, contrary to the finding of Saenger & Stubbs (1994) and Stubbs & Saenger (1996), we propose that Edward Palmer was not the source of the suggestions of Chinese inscriptions existing on the Investigator Tree.

## INVESTIGATOR TREE – OBSERVATIONS FROM HISTORICAL DOCUMENTS

As detailed above, the primary historical accounts that cite first-hand observations of inscriptions on trees at Sweers Island and which are mostly attributed to the Investigator Tree include: Baines (1856–1857, 1857), Bourne (1862), Chimmo (1857), Gulliver (1889, see Anon., 1889e), Henne (1861–1862), Landsborough (1862), Landsborough (1866–1871), MacDonald (1866, see Anon., 1933), Napier (1876), Norman (1861–1862), Pennefather (1880), Phillips (1866–1868), Roth (1901) and Stokes (1846). Secondary

historical sources include several newspaper articles; some of these contain information furnished by Captain Jones, e.g. *The Brisbane Courier* (Anon., 1889d), *The Daily Northern Argus* (Anon., 1889c), *The Maryborough Chronicle, Wide Bay and Burnett Advertiser* (Anon., 1889f), *The Morning Bulletin* (Anon., 1889a), *The Queenslander* (Anon., 1889b), *The Queenslander* (Anon., 1907), *The Queenslander* (Anon., 1933), J. J. Knight (1895) and Palmer (1903, p. 26). Collectively these documents list 28 different inscriptions, all by eyewitness observers, on at least three different trees that were recorded between 1841 and 1901 (Table 1).

Inscriptions 27 and 28 (see Table 1) are attributed to two trees besides the Investigator Tree, meaning a total of three trees had inscriptions. Inscription 27, Frost's funerary text, was carved into a tree near his grave (Henne, 1861–1862). McCrae's engraving, after Handfield's sketch, confirms Henne's observation of a tree inscribed with Frost's funerary text (Figure 4). This tree was approximately 1 km from the Investigator Tree. For listing purposes (see Table 1), it should be noted that Frost's funerary text has been counted as one inscription, but it contains 45 inscriptions (separate words and numerical characters):

> In memory of Mr James Frost. V.N. Gunner of H.M.C.S. Victoria who was killed near this spot by the accidental discharge of a gun the 31st day of December 1861. Age 28 yr. For ten years a faithful Servant of his Queen and Country RESURGAM.

Inscription 28, "Messenger", is a second "Messenger" inscription recorded by Landsborough as being on another tree that was not the Investigator Tree (Landsborough, 1866–1871). Therefore, two "Messenger" inscriptions were observed (Inscriptions 9 and 28). Chimmo (1857, p. 362) noted that the *Torch*'s name was not added to the Investigator Tree because it would be "sacrilegious" to the memory of Flinders and the *Investigator*. This suggests that the "Chimmo" inscription (Inscription 10) was also inscribed on another tree: not the Investigator Tree. Therefore, the historical documents reveal that there were other trees, including some close to the Investigator Tree, that were also inscribed.

## EXTANT PORTIONS OF THE INVESTIGATOR TREE

The Investigator Tree transitioned from a maritime marker in the Sweers Island landscape to a curated artefact relocated to Brisbane in late 1888. The inscribed tree was removed from Sweers Island by Captain J. W. Jones, the Gulf of Carpentaria Pilot, who "decided to cut it down and have it preserved" (Anon., 1907) because of its damaged state following a cyclone in March 1887 that "so injured the tree that it began to decay and was generally falling" (Anon., 1889d; Knight, 1895, p. 7). However, The Captain Thomson Catalogue (1986) states that the removal of the Investigator Tree to Brisbane was made at Captain William Campbell Thomson's suggestion. Thomson was a sea captain and keen collector and creator of natural and cultural curios (Captain Thomson Catalogue, 1986). Removal of the Investigator Tree, first to Normanton with Captain Jones aboard the S.S. *Vigilant*, and then on to Brisbane by coastal steamer, possibly with Captain Thomson, meant the translocation of most, but not all, of the Investigator Tree's inscriptions (Anon., 1889c). For instance, Roth (1901) recorded five of the more legible inscriptions on the remaining tree "butt", during his 1901 visit to Sweers Island.

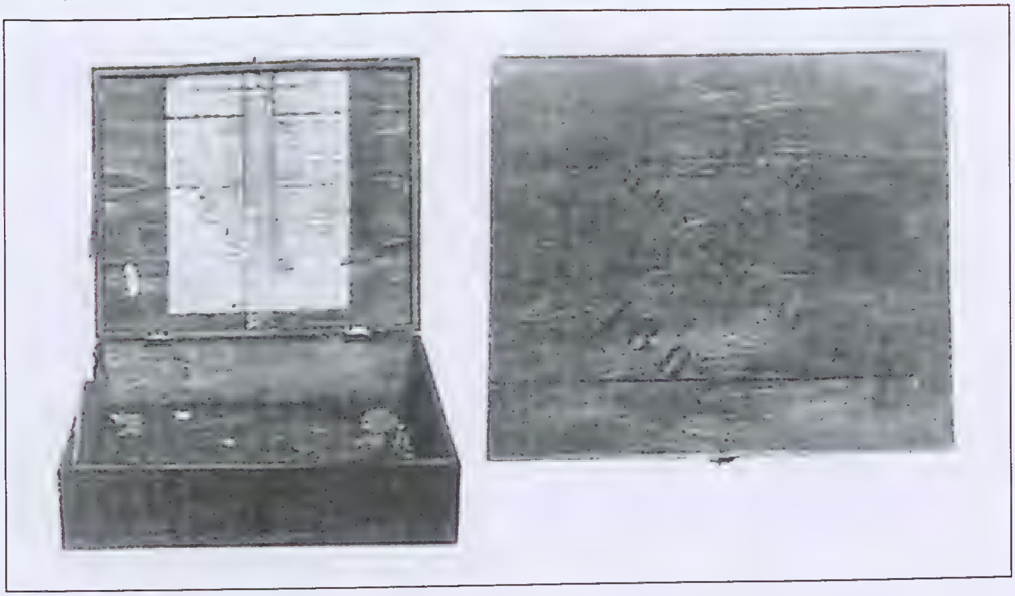
The part of the Investigator Tree removed in 1888 was cut in two, becoming Portion 1 (with inscriptions) and Portion 2 (without inscriptions), either at Sweers Island, to facilitate transportation to Brisbane, or once the tree arrived in Brisbane. Once in Brisbane, Portion 1 (Queensland Museum Registration No. H43029.1) first went to the Brisbane Port Master, Captain G. P. Heath R.N., before it was donated to the Brisbane Museum (now the Queensland Museum) under the Curator/Directorship of Charles de Vis (Anon., 1889d; Knight, 1895, p. 7; Queensland Museum, 2017). The Queensland Museum donor register records Portion 1's arrival at the Museum on 13 February 1889 (Queensland Museum, 2017).

Portion 2, together with branches of the Investigator Tree, became the property of Captain Thomson, who fashioned an oval space on Portion 2 of the Investigator Tree for the insertion of a painting/drawing. Thomson also constructed a box from the Investigator Tree's branches (Captain Thomson Catalogue, 1986) (Figure 6). Portion 2 was only reunited with Portion 1 in 2009 when it was donated to the Queensland Museum (acquisition date 17 July 2009) (Queensland Museum Registration No. H43029.2) by Mrs D. M. Thomson whose late husband was the grandson of Captain Thomson. Only Portion 1 is on public display at the Queensland Museum.

TABLE 1. Historically recorded Investigator Tree inscriptions. Inscriptions 27 and 28 are recorded as appearing on trees other than the tree inscribed with "Investigator". **Bold** denotes extant inscriptions observable on Portion 1 of the Investigator Tree held by the Queensland Museum. Note that capitalisation mirrors that adopted in the inscription.

| Number | Inscription | Refers to |
|---|---|---|
| 1 | LOWY 1781 | Supposed Dutch ship |
| 2 | 1798 "with some Chinese characters" | Chinese characters with date |
| 3 | **INVESTIGATOR** | Name of Flinders' ship (original inscription) |
| 4 | **INVESTIGATOR** 1802 | Name of Flinders' ship (carved by Baines, 1856) |
| 5 | **BEAGLE 1841** | Name of Stokes' ship and the date it was at Sweers Island |
| 6 | STOKES 1841 | Commander John Lort Stokes of the *Beagle* |
| 7 | NAE NOV 20 1856 | North Australia Expedition date on Sweers Island |
| 8 | **ROBERT DEVINE** | Captain of *Messenger*, 1856 |
| 9 | **Messenger** | Ship that replaced the *Tom Tough* on the NAE expedition |
| 10 | CHIMMO 1856 | Commander of *Torch* – Lieutenant William Chimmo |
| 11 | J. SWAN | Carnarvon resident, Sweers Island |
| 12 | P. W. ARMSTRONG, DEC, 1855 | Carnarvon landowner (the 1855 date could be a misreading of "1866") |
| 13 | BN | |
| 14 | W. S. HOWELL | Misreading of "W. SHOWELL" aboard *Messenger*, 1856 |
| 15 | KARL TEATS 1856 | Possible crew member aboard *Torch* or *Messenger* |
| 16 | W. SOLBY | Misreading of "W. Selby" aboard *Messenger* |
| 17 | THE EXPEDITION 1861 | Landsborough's search party for Burke and Wills, 1861 |
| 18 | NORMAN | Captain of *Victoria*, 1861 |
| 19 | J. Martin 1861 | Possibly Mr Martin aboard *Firefly*, son of the owner of *Firefly* |
| 20 | L. H. x.x.S. 1861 | |
| 21 | J. AUSTIN | Also recorded as "A. Austin" with 1861 date |
| 22 | W. LANDSBOROUGH 1866 | William Landsborough with date he became Carnarvon resident |
| 23 | W. J. HAY | |
| 24 | W .C. A. MILES | |
| 25 | A.H.T. 1866 | Possible misreading of "A.B.T. 1866" – Carnarvon landowner A. B. Thomas |
| 26 | D. C. CLOUSTON 1866 | |
| 27 | Funerary text of James Frost | Gunner aboard *Victoria*, 1861, and fatally shot |
| 28 | MESSENGER | Ship that replaced the *Tom Tough* on the NAE expedition |

FIGURE 6. Box made by Captain Thomson from branches of the Investigator Tree. "H.M.S. Investigator 1802" is written on the lid (dimensions 29 cm × 34.4 cm, depth 10.6 cm) (Captain Thomson Catalogue, 1986).



## APPROACH

Our comprehensive review of primary and secondary sources informs and supports our physical inspection of Portions 1 and 2 of the Investigator Tree. Quantitative and qualitative methods were employed to identify, and in some cases translate, potential inscriptions and other features. Measurements of both portions of the Investigator Tree were recorded (length and circumference). Inscriptions were identified and the possible words transcribed, and inscription measurements were recorded: total inscription length and height, word and/or word and date length and height, and individual letter or number length and height. The depth of inscriptions was also recorded, where possible. Location identifiers were assigned to areas of Portion 1 only and named Panels 1–5 which identify five horizontal planes of the cylindrical tree trunk (see Table 2). Panel 5 is in immediate contact with the surface the trunk lies on, so no observations could be made of Panel 5, as turning the Investigator Tree was not permitted. Photographs of both portions of the Investigator Tree's inscriptions/features were taken, for recording purposes.

TABLE 2. Investigator Tree's extant inscriptions according to their panel position, and their designated number for recording purposes. Note that capitalisation mirrors that adopted in the inscription.

| Panel | Number | Extant inscriptions | Comment |
|---|---|---|---|
| 1 | 1 | BEAGLE 1841 | |
| 2 | 2<br>3 | INVESTIGATOR<br>Indecipherable | Cut by Baines, 1856 |
| 3 | 4<br>5<br>6<br>7 | \V<br>\<br>INVESTIGATOR<br>Messenger | Attributed to Flinders, 1802 |
| 4 | 8 | ROBERT . DEVINE | |
| 5 | | Unknown | Not inspected |

## INSCRIPTIONS

Of the 28 inscriptions identified from the archival records and attributed to trees on Sweers Island in the nineteenth century, two of the inscriptions can be definitively attributed to trees other than the Investigator Tree. The remaining 26 inscriptions have been historically attributed to the Investigator Tree. Examination of extant Portion 1 of the Investigator Tree reveals eight inscriptions/markings which suggests, given the surface area they cover, that the remaining 26 inscriptions were likely never all inscribed on extant Portion 1 of the Investigator Tree. Our analysis of the artefactual remains supports our contention that the term 'Investigator Tree' was a collective term used to describe multiple inscribed trees.

### *Investigator Tree – Portion 1*

The Investigator Tree is a *Celtis paniculata* (native hackberry or silky celtis) (Queensland Museum, 2017). The differences between the two surviving portions of the Investigator Tree are acute, both in size and the number of inscribed areas (Table 1). Portion 1 is a cylindrically hollow trunk, while Portion 2 is laterally truncated. Portions 1 and 2 clearly belong to the same trunk. Knight's (1895, p. 7) measurements, together with physical inspection of Portions 1 and 2, indicate that the two portions can join. Knight's (1895, p. 7) measurements originally came from *The Brisbane Courier* (Anon., 1889d) which stated that they were recorded while the tree was still at the Brisbane Post Office in 1889 (Queensland Museum, 2017) (Table 3).

On Portion 1 there are eight inscribed areas (see Table 4) that have been numbered and assigned to Panels 1–4 (Table 2). All the inscriptions have been cut lengthways on the trunk and would have been most easily read by walking anticlockwise around the tree. For recording purposes, the inscriptions were numbered according to the order they appear while hypothetically traversing anticlockwise around a hypothetically upright trunk and reading from top to bottom. There is a general consistency to each inscription's letter/number height (Table 5).

Five of the eight extant inscriptions are decipherable and include two inscriptions that read "Investigator" (Tables 2, 4). The original "Investigator" inscription (Inscription 6) (Tables 2, 4; Figure 7), attributed to Flinders (1802), is finer and not as deeply inscribed as the second "Investigator" inscription (Inscription 2) (Tables 2, 4; Figures 7–8), carved by Thomas Baines in 1856. Some letters are only partially visible on the original "Investigator" inscription and so are hard to identify (e.g. "G", "A", "O", "R"). The second "T" cannot be seen at all. Nevertheless, the examination of the two "Investigator" inscriptions clearly shows that even today both inscriptions are clearly legible and can be read as "Investigator". Two other decipherable inscriptions are "Beagle 1841" (Inscription 1) (Figure 8; Table 4) and "Robert Devine" (Inscription 8) (Table 4). The "Rober" letters are less defined than the "T" of "Robert", which explains the misrepresentation of this inscription in the archives as "T Devine" (e.g. Anon., 1889d; Knight, 1895, p. 7). Inspection of the "Robert Devine" inscription dispels Saenger & Stubbs' (1994, p. 70) view that the "Rober" letters of "Robert Devine" must have remained on the butt portion of the Investigator Tree that remained on Sweers Island. Inscription 7, "Messenger", is harder to recognise (Table 4), its inscribed double "s" and Baines' sketch (Figure 14) confirming its presence. The "Messenger" inscription is the only inscription written in lower case roman letters after its capital "M". All the other extant inscriptions are written in upper case roman letters.

### *Investigator Tree – Portion 2*

There are no inscriptions on Portion 2 (Figures 9–10). However, there is an oval area, 215 mm × 135 mm, that has been cut into the trunk's surface: at its deepest it measures 30 mm (Figure 9). An oval timber sheet, which is held in place by four copper screws, has been inserted into this space. Two fine tacks 1 mm wide have been nailed into the oval timber sheet, middle top and middle bottom of the oval, and both protrude from the surface. An auction catalogue of Captain Thomson's collection revealed that this oval space once housed a drawing of the Investigator Tree (Figure 11) (Captain Thomson Catalogue, 1986). It is assumed that Portion 2 remained unsold after the 1986 Pickles auction, because it was still in the Thomson family when it was donated to the Queensland Museum in 2009. The whereabouts of the inserted drawing (Figure 11) is unknown.

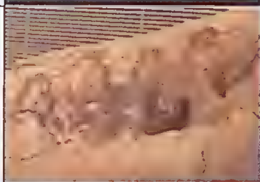
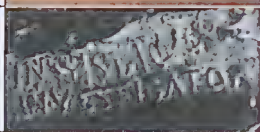
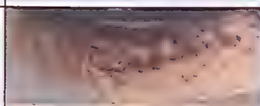
### *Investigator Tree – Evidence from Artistic Interpretations*

The first artistic rendering of the Investigator Tree is found in Stokes' 1846 publication *Discoveries in Australia* (Figure 12). It shows the curve of a coastal bay in the background, the "Investigator" inscription on a tree, an armed figure standing in proximity to the tree to give a sense of proportion, and three trees close to the inscribed Investigator Tree. The scale of the "Investigator" inscription is exaggerated. The second drawing of the Investigator Tree is attributed to Chimmo (1857) (Figure 13). The rendering of the tree, the "Investigator" inscription and the background are reminiscent of Stokes' drawing. However, Chimmo's drawing focuses on the tree only, and it is the first to represent the Investigator Tree as a stand-alone tree.

TABLE 3. Length and circumference of Investigator Tree. Note that Knight's (1895) imperial measurements have been converted to metric.

| Portion | Length (mm) | Circumference (mm) (2017) | Diameter (mm) (Knight, 1895, p. 7) |
|---|---|---|---|
| 1 | 2770 | 1650 (base of trunk) | 790 (2 ft 7 in. – base of trunk) |
| | | 1120 (at "B" of Beagle) | |
| | | No top measurement | 380 (1 ft 3 in. – top of trunk) |
| 2 | 615 | 380 | |

TABLE 4. Extant Investigator Tree inscriptions (Photographs: Sarah Collins, 2017, except Inscriptions 2 and 6, State Library of Queensland, Negative No. 18926). Note that capitalisation mirrors that adopted in the inscription.

| Panel | Number | Inscription | Photograph | Length (mm) | Height (mm) |
|---|---|---|---|---|---|
| 1 | 1 | BEAGLE |  | 820 | 210–250 |
| 1 | 1 | 1841 |  | 495 | 210–250 |
| 2 | 2 | INVESTIGATOR (Baines below) |  | 1020 | 95–115 |
| 2 | 3 | Indecipherable | No Image | | |
| 3 | 4 | \ V Indecipherable |  | 1210 | |
| 3 | 5 | \ |  | 130 | |
| 3 | 6 | INVESTIGATOR (original above) |  | 1150 | 120–180 |
| 3 | 7 | Messenger |  | 510 | 50–95 |

| Panel | Number | Inscription | Photograph | Length (mm) | Height (mm) |
|---|---|---|---|---|---|
| 4 | 8 | ROBERT . |  | 510 | 70–132 |
| 4 | 8 | DEVINE |  | 570 | 90–115 |

TABLE 5. Letter height, height variation and maximum inscription depth of the Investigator Tree inscriptions. Note that capitalisation mirrors that adopted in the inscription.

| Number | Inscription | Letter height (mm) | Height variation (mm) | Inscription depth (mm) |
|---|---|---|---|---|
| 1 | BEAGLE | 210–250 | 40 | Not recorded |
| 1 | 1841 | 210–250 | 40 | 20–65 |
| 2 | INVESTIGATOR | 95–115 | 20 | 10–20 |
| 6 | INVESTIGATOR | 120–180 | 60 | NA |
| 7 | Messenger | 50–95 | 45 | Not recorded |
| 8 | ROBERT | 70–132 | 62 | 5–10 |
| 8 | DEVINE | 90–115 | 25 | 5–15 |

FIGURE 7. The "Investigator" inscriptions on the Investigator Tree: Panel 3, Inscription 6 attributed to Matthew Flinders (above); and Panel 2, Inscription 2 carved by Thomas Baines (below) (State Library of Queensland, Negative No. 18926).

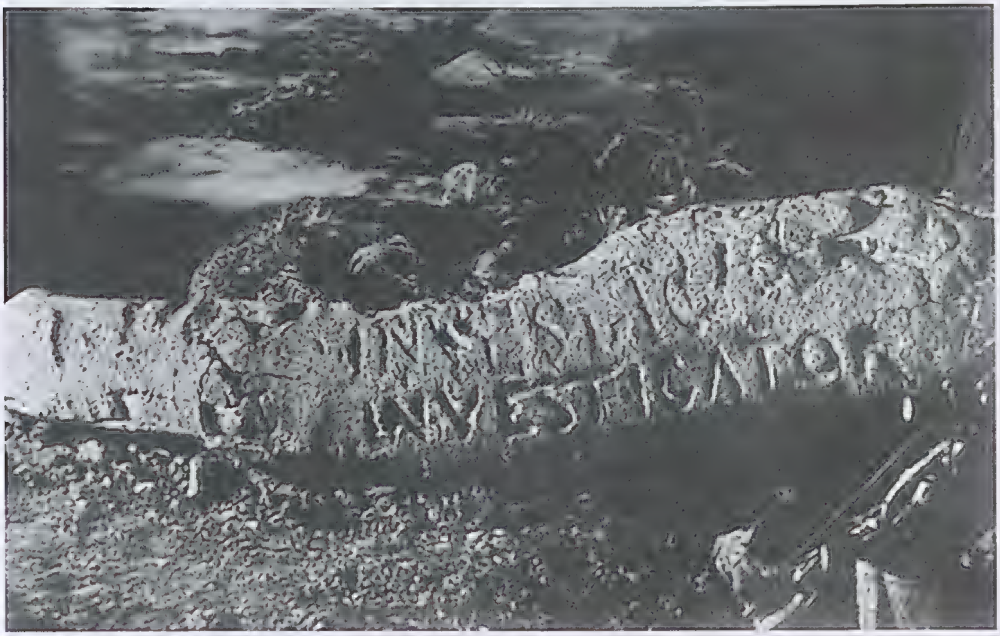


FIGURE 8. Panel 1, Inscription 1, "Beagle 1841", attributed to Stokes (below); and Panel 2, Inscription 2, "Investigator", carved by Thomas Baines (above) (Queensland Museum, H43029).


FIGURE 9. Investigator Tree, front of Portion 2 (Photograph: Queensland Museum, 2019).

FIGURE 10. Investigator Tree, back of Portion 2 (Photograph: Queensland Museum, 2019).

FIGURE 11. Portion 2 of the Investigator Tree as it appeared at the Pickles auction, Sydney, 1986, in the Pickles Auction Catalogue of the Thomson Collection (Captain Thomson Catalogue, 1986).

FIGURE 12. The first artistic portrayal of the Investigator Tree, Sweers Island (Stokes, 1846, p. 270).

FIGURE 13. The Investigator Tree (Chimmo, ca 1857) (State Library of Queensland, Negative No. 1089502).

The third drawing of the Investigator Tree was by Thomas Baines in 1856 (Braddon, 1986, p. 138) (Figure 14). Baines' depiction shows three of the tree's inscriptions: the original "Investigator" inscription, the "Investigator" inscription carved by Baines, and part of the "Messenger" inscription. Baines' sketch confirmed the extant "Messenger" inscription on Portion 1. Baines' sketch includes five seated figures, members of the NAE party, and the other nearby trees. Perhaps Baines' (1856–1857) reference to "smaller trunks" when he records "nearly all the men ... carved their names on some smaller trunks of the Investigator's tree" refers to the smaller nearby trees depicted by Stokes and Baines in their drawings (Figures 12 and 14). Baines' sketch with its accompanying caption (partly quoted above) strongly implies that several trees/tree trunks were inscribed by at least 18 men (based on the size of Baines' seaborne party) (see Appendix A). From Baines' sketch, one can make out where the lower cut to the tree occurred and imagine the remaining "butt" on which Roth records seeing inscriptions in 1901. The fourth representation is Phillips' (1866–1868) drawing of the Investigator Tree which appears on his survey of Point Inscription to indicate the location of the tree in the landscape (Figure 2). Phillips' later survey of Sweers Island and the township of Carnarvon does not illustrate the tree. Instead he uses text to describe where the tree is positioned: "Note. The space reserved out of Allotment 1 of Sec:11 contains the Tree, marked by Flinders in 1802 with the name of his vessel, the 'Investigator'" (Survey Plan C1351, Department of Natural Resources, Mines and Energy, Queensland) (Figure 15 referencing Figure 3). The fifth drawing is Mr B. Barker's reproduction of MacDonald's original pocketbook sketch of a stand of trees that includes the Investigator Tree, from when MacDonald was on Sweers Island in 1866 (Figure 5). The cottage erected by Carnarvon landowner Mr Longstaff is an addition to the sketch by Barker. The sixth image is

attributed to Knight (1895, p. 6) and is the first image of the Investigator Tree in a museum setting and the only one to show Stokes' "Beagle 1841" inscription (Figure 16). It also exaggerates the size of the tree in relation to the two Victorian figures pictured admiring it, possibly an artistic device used to accentuate the tree's importance.

The seventh and final drawing of the Investigator Tree is the one that was inserted into the oval space on Portion 2 of the Investigator Tree (Figures 11, 17). Its provenance suggests that Captain Thomson commissioned an artist to create this representation. This drawing's strong similarity to the drawings of Stokes (1846) and Chimmo (1857) suggests the artist may have used either of these drawings to guide their work. This is the first and only depiction of the Investigator Tree with Indigenous figures, one seated and the other standing holding a spear. The addition of Indigenous figures may have been deliberately made to appeal to nineteenth-century Aboriginal artefact collectors. However, the Flinders association is also reinforced in the text accompanying the drawing, which reads: "[s]ite of Investigator Tree from Sweers Island inscribed by Lieut. Flinders 1802" (Captain Thomson Catalogue, 1986). The insertion of this drawing into the oval space on Portion 2 of the Investigator Tree transformed Portion 2 into a cultural curiosity, and is one of several Investigator Tree memorabilia either manufactured or commissioned by Captain Thomson to appeal to nineteenth-century collectors of cultural curios. Another is a box made from smaller branches of the Investigator Tree (Captain Thomson Catalogue, 1986) (Figure 6). The only known, *in situ*, photograph of the Investigator Tree completes the visual/artistic interpretations of the Investigator Tree (Figure 18). This photograph confirms that the Investigator Tree shown on the right of a clump of trees was not an isolated tree.

FIGURE 14. Baines' sketch of the Investigator Tree, 1856. Baines' text accompanying this drawing reads: "Tree near Flinders' Well on Sweers Island Gulf of Carpentaria with the names of the Investigator and the Beagle carved on it – the uppermost is the original name carved by Flinders crew, the lower and more distinct was cut by myself to mark the spot visited by the old navigator when his own might be effaced. The Messengers name is below" (Braddon, 1986, p. 138).

FIGURE 15. Phillips' reference to the Investigator Tree on his 1866 Sweers Island/Carnarvon map (Survey Plan C1351, Department of Natural Resources, Mines and Energy, Queensland).

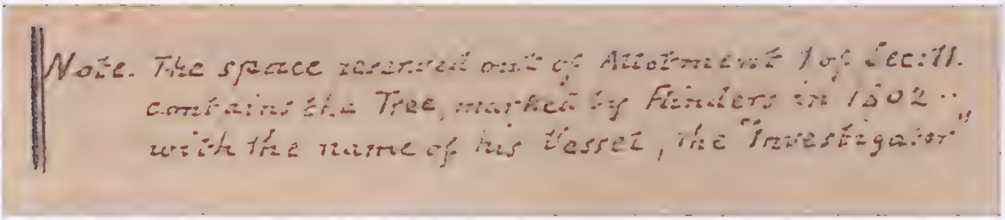



FIGURE 16. The Investigator Tree (Knight, 1895, p. 6).

FIGURE 17. Oval space on Portion 2 of the Investigator Tree with a drawing inserted (Captain Thomson Catalogue, 1986).

## ONE OR MANY INVESTIGATOR TREE/S?

An unexpected outcome of the detailed review of archival sources has been the clear finding that there were at least three inscribed trees on Sweers Island and that they were not confined to one location. They include the tree with "Investigator" carved into it twice, the tree with Frost's funerary text near his grave, and the tree noted specifically by Landsborough as also having "Messenger" inscribed on it. The "Chimmo" inscription could have been on the same tree as the second "Messenger" inscription or on a fourth tree. Therefore, the number of inscriptions cited in the historical records suggests the likelihood that more than three trees were inscribed. Furthermore, it appears

that the term 'Investigator Tree', used by observers of the inscriptions, was not necessarily singling out one tree, but rather it may have become a descriptive term for inscribed trees on Sweers Island generally. Drawings and one nineteenth-century photograph confirm that the Investigator Tree was one of several trees growing together, while the written records of some observers refer to the Investigator Tree as a tree with many trunks. Nevertheless, Diedrich Henne and William Landsborough are the only two observers of the tree inscriptions to explicitly state they observed inscriptions on trees that were not the tree with "Investigator" inscribed on it.

Of the eight extant Investigator Tree inscriptions, five can be identified and correlated to the 28 Investigator Tree inscriptions recorded in the historical records. Of the remaining three extant inscriptions, two cannot be identified because of significant deterioration in the inscriptions, and one is a mark that does not appear to have been previously recorded (Inscription 5, Panel 3). The most detailed lists of inscriptions attributed to the Investigator Tree are by MacDonald in 1866 (Anon., 1933) who lists nine inscriptions; B. J. Gulliver in 1867 (Anon., 1889e) who lists 15 inscriptions; and the seven inscriptions listed by the 1889 newspapers (e.g. *The Daily Northern Argus* (Anon., 1889c)) which are repeated by Palmer (1903, p. 26). Other observers tend to only mention the "Investigator" inscription with possibly one or two other inscriptions, which suggests the importance felt by the observers for the Flinders-related inscription. By 1901 when Roth visited Sweers Island, the Investigator Tree was no longer *in situ*; only an inscribed tree stump remained, which helps explain why three (Inscriptions 11, 12, 13; see Table 1) of the five inscriptions he recorded are not listed by anyone else. Before the tree's removal they were three inscriptions among many, but following the tree's removal they became more noteworthy because they were three of only five legible inscriptions remaining on a tree stump.

FIGURE 18. Photograph of a group of people on Sweers Island positioned in front of the Investigator Tree [centre], ca 1870 (State of Library Queensland, Negative No. 90903).

The difference between the number of historically observed inscriptions (28) and the extant inscriptions (8) (of which 5 are legible) means that about 20 inscriptions are physically unaccounted for. If the two inscriptions attributed to other trees (Inscriptions 27 and 28) and the five inscriptions noted by Roth in 1901 on the remaining stump of the Investigator Tree are further subtracted, that leaves 13 inscriptions physically unaccounted for that one would expect to find on Portion 1. That any of these missing inscriptions remain unobserved on Panel 5 of Portion 1 of the extant Investigator Tree is doubtful. As stated earlier, Panel 5 could not be inspected; however, the cylindrical nature of the trunk meant that it was not a large area that remained unobserved. Therefore, the 13 unaccounted-for inscriptions support the multi-tree finding. Put another way, if four-fifths (4 out of 5 panels) of the Investigator Tree have eight inscriptions, it seems improbable to find 13 further inscriptions on one-fifth of the trunk. Even if the number of 13 is reduced to 9 to accommodate the inscriptions only cited by the 1889 newspapers and Palmer (Inscriptions 1, 2, 10, 18; see Table 1), the probability is still low.

## THE QUESTION OF PRE-FINDERS INSCRIPTIONS

Past studies have been particularly critical of Palmer's list of Investigator Tree inscriptions (e.g. Saenger & Stubbs, 1994; Stubbs & Saenger, 1996) which, since its publication in 1903, became an often-cited source for subsequent newspaper articles on the Investigator Tree. However, this paper establishes that Palmer's list was an exact copy of an earlier list first published in 1889 and probably attributable to Captain Jones. This shift in the Palmer (1903, p. 26) list's provenance has two key implications. First, it means that Palmer was not "the originator of the Chinese inscription myth" (contra Stubbs & Saenger, 1996, p. 95). Second, all criticism of the seven listed inscriptions must shift to Captain Jones, the probable author of the inscription list published in several 1889 newspaper articles. This criticism aimed hitherto at Palmer has centred on some historical inaccuracies accompanying the listed inscriptions and the fact that four of the inscriptions – "Lowy 1781", "1798 with some Chinese characters", "Chimmo 1856" and "Norman" – are not recorded by other observers.

Of these, the first two appear to cause the most controversy for their pre-*Investigator* dates and for the implication that Dutch and Chinese ships had arrived at Sweers Island. The Dutch ship *Lowy* with the date 1781 has not been identified in the historical record, while the assertion that it was commanded by Captain Tasman (Anon., 1889c; Palmer 1903, p. 26) is impossible. Tasman's activity in the Gulf of Carpentaria was more than a century earlier. This error, along with the incorrect assertion that Robert Devine was a first lieutenant aboard the *Investigator*, has diminished the list's credibility for some researchers. However, there is conclusive evidence of pre-1802 visits to Sweers Island. Flinders noted finding human remains on Sweers Island, as well as a piece of timber from a ship and evidence of trees that had been cut with axes on neighbouring Bentinck Island, during his stay on Sweers Island in 1802. Flinders concluded that perhaps an East India ship had been shipwrecked there (Flinders, 1814, p. 147). Oertle et al. (2014, p. 65) documented Macassan ceramics and tamarind trees on neighbouring Bentinck and Fowler Islands, which they associated with seasonal bêche-de-mer fishing activities of Macassans. Pre-Flinders non-Indigenous activity in the Sweers Island area is confirmed. Furthermore, Baines (1856–1857) notes in 1856 that while walking along the beach at Sweers Island he came across "the bowsprit of a Chinese junk". Also, Captain Jones states in his letter to Captain Heath dated 10 November 1888 that as well as the Investigator Tree he was sending him "the butt end of a mast of a Chinese junk which was wrecked on Sweer's Island in 1798" (Anon., 1889d).

Stubbs & Saenger (1996, pp. 102, 105) argue that the so-called Dutch and Chinese inscriptions, posited by Pennefather in 1880 and by Palmer in 1903, were an "invention" perpetuated by twentieth-century writers. They further assert that the so-called Chinese inscriptions, posited by Palmer (1903), were a possible misreading of the faded original "Investigator" inscription (Saenger & Stubbs, 1994, p. 68; Stubbs & Saenger, 1996), a misunderstanding perhaps compounded by there being two "Investigator" inscriptions on the Investigator Tree. While this is a possible explanation, as previously stated, both "Investigator" inscriptions can be clearly read and understood, even today.

This paper contends that the possibility of Chinese characters inscribed on a tree at Sweers Island should be left open for three reasons. First, given that several trees on Sweers Island are now known to have been inscribed, a tree with Chinese characters cannot be so easily discounted. Second, the script of the Macassans, who are known to have been visitors to the South Wellesley Islands before and after Flinders' arrival, may have been carved on a Sweers Island tree

and misinterpreted as Chinese characters. Finally, when Palmer was believed to be "the originator of the Chinese inscription myth" (Stubbs & Saenger, 1996, p. 95), a contributing factor in arguing against Palmer's list and its contentious inscriptions was that Palmer was not an eyewitness to the Investigator Tree and its inscriptions. However, now that the Palmer list's origin can be traced to 14 years earlier and Captain Jones, an eyewitness to the Investigator Tree and its inscriptions, the list becomes more credible. Yet, while the newly reported available evidence lists pre-Flinders inscriptions once being on the Investigator Tree, conclusive evidence remains elusive.

"Chimmo 1856" and "Norman" are the other two Jones-related inscriptions not mentioned by other observers. The "Chimmo 1856" inscription referring to Captain Chimmo of the *Torch* is questioned by Saenger & Stubbs (1994, p. 69) and Stubbs & Saenger (1996, p. 103) because of its contradiction with Chimmo's statement that the *Torch*'s name was not added to the inscriptions on the Investigator Tree as it would be "sacrilegious" to do so. Chimmo's terminology speaks to the veneration held for Flinders. However, this should not mean that the *Torch*'s or Chimmo's name was not inscribed onto a different tree. For instance, Chimmo (1857, p. 366) notes that the ship's name (*Torch*) and date were cut in large letters on a tree at the Albert River as a message for Gregory's party, which was sighted by the Gregory party's seaborne contingent led by Baines (Baines, 1856–1857). Baines (1856–1857) also notes finding a plank inscribed with "Torch" at Beagle's well, near Point Inscription on Sweers Island. Therefore, given that there was a precedent to inscribe, the claim that there was a "Chimmo 1856" inscription should not be dismissed. Questioning the veracity of an observed inscription based on the infrequency it is recorded is history by selectivity that fails to consider the artefact's changing physical appearance over time, as well as the personal predilection of observers to record some inscriptions while ignoring others. As noted earlier, most of the observers of the Investigator Tree inscriptions mention the "Investigator" inscription due to its association with the illustrious Matthew Flinders but do not elaborate beyond that in their accounts. Instead we must make do with "other names are also inscribed" (Bourne 1862, p. 11). This raises the question of how many other inscriptions may never have been recorded and/or have deteriorated over time. A case in point is Dugal Robison's (1867–1868, p. 88) claim that it was commonplace, throughout their journeying, for the crew of S.S. *Eagle* to mark trees with the "Captain's initials F C [Francis Cadell] and the number of the camp". The initials "F C" are found at Wirrikiwirriki Cave on the north-eastern coast of Sweers Island, but not among the recorded observations of Investigator Tree inscriptions (Collins, 2017).

## CONCLUSION

The Investigator Tree/trees and associated inscriptions are historically significant not only as a record of the early maritime exploration and colonial settlement of northern Australia in the nineteenth century, but also as a rare preserved artefact representative of the European practice of inscribing trees in Australia. This paper's comparative analysis, for the first time, of the 28 inscriptions historically observed and attributed to the Investigator Tree with the eight extant inscriptions/markings on Portion 1 of the Investigator Tree demonstrates how the artefactual record informs the historical archive and vice versa. In doing so, this research reveals that there were at least three inscribed trees on Sweers Island during the nineteenth century, which leads to our conclusion that the term 'Investigator Tree' may have become a collective term to describe inscribed trees on Sweers Island generally. The question of earlier pre-Flinders inscriptions of Dutch or Chinese origin is controversial and, despite the efforts of this paper's research, remains circumstantial. However, although a definitive answer is not forthcoming, the Gulf of Carpentaria's history of Dutch and Macassan visitation to the area predating Flinders is factual which, in the context of multiple inscribed trees on Sweers Island, means Dutch and Chinese inscriptions on the Investigator Tree/trees becomes a possibility. This paper also records Portion 2 of the Investigator Tree for the first time. Together, these two portions of a once unified whole are testament to the power of association with the venerated Matthew Flinders. Subsequent inscription makers left marks of self-expression to assert their presence, identity or survival, in deference to Flinders' "Investigator" inscription. By doing so, they cemented their historical present into the fabric of the Investigator Tree, while also writing themselves into the future.

## APPENDIX A

People on the North Australia Expedition (NAE), 1855–1856, and ships *Tom Tough* and *Messenger* (incomplete)

*Note*: Not all went to Sweers Island. **Bold** denotes five of the seven NAE party members who overlanded from Victoria River to the Gulf of Carpentaria; they never visited Sweers Island. The others travelled by sea and arrived at Sweers Island (November 1856) either aboard the *Messenger* or with Baines in the longboat (Baines, 1857, pp. 14, 15).

| | Name | Position/Title | Source |
|---|---|---|---|
| 1 | **Augustus C. Gregory** | Commander | Baines, 1857, p. 5 |
| 2 | **Henry C. Gregory** | Assistant Commander | Baines, 1857, p. 5 |
| 3 | **Ferdinand von Mueller** | Dr/Baron, Botanist | Baines, 1857, p. 5 |
| 4 | **J. R. Elsey** | Doctor & Naturalist | Baines, 1857, p. 5 |
| 5 | Mr Gourlay | Captain | Baines, 1857, p. 5 |
| 6 | Thomas Baines | Artist & Storekeeper | Baines, 1857, p. 3 |
| 7 | W. Showell | Stockman | Baines, 1856–1857 |
| 8 | J. S. Wilson | Geologist | Baines, 1857, p. 5; Baines, 1856–1857 |
| 9 | Mr Flood | Collector & Preserver | Baines, 1857, p. 5; Baines, 1856–1857 |
| 10 | **Robert Bowman** | Stockman | Baines, 1856–1857, p. 137 |
| 11 | Charles Dean | Stockman | Baines, 1857, p. 7; Baines, 1856–1857 |
| 12 | J. Fahey | Stockman | Baines, 1857, p. 7; Baines, 1856–1857 |
| 13 | W. Dawson | Stockman | Baines, 1856–1857, p. 137 |
| 14 | S. MacDonald | Stockman | Baines, 1856–1857, p. 137 |
| 15 | Mr Humphreys | Second Overseer | Baines, 1857, p. 8 |
| 16 | Mr W. Graham | | Baines, 1857, p. 10 |
| 17 | Mr G. Phibbs | Overseer | Baines, 1857, p. 10; Baines, 1856–1857 |
| 18 | J. Melville | Stockman | Baines, 1856–1857 |
| 19 | Mr Adams | Sailor | Baines, 1857, p. 8 |
| 20 | Robert Devine | Captain of *Messenger* | Baines, 1857, p. 10 |
| 21 | Mr Harris | | Baines, 1856–1857 |
| 22 | Mr W. Selby | | Baines, 1856–1857 |
| 23 | Mr John Smith | Sailor | Baines, 1856–1857 |

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## AUTHOR PROFILES

Sarah Collins is an archaeologist currently studying towards a PhD at James Cook University (Cairns). Sarah's research interest and passion lies in revealing the multifarious aspects of early European settlement sites in Australia through historical and archaeological materials.

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# BOOK REVIEW

*Feast on Phytochemicals*

Natural health-boosting compounds in fruit, vegetables, herbs and spices, including Australian bush food plants

By Paul Williams

Vegetation Management Science, 2019, Malanda Queensland, 276 pp. Paperback

In an age of chronic diseases that are associated with fast food and poor lifestyle choices, there appears to be a 'turn in the wheel' which focuses on food as medicine and the science behind the phytochemicals found within the plant kingdom. The author of *Feast on Phytochemicals*, Paul R. Williams (PhD), demonstrates how empirical knowledge of the health benefits of various foods is now being backed by science. Paul is a plant ecologist focused on fire and weed management, who has also developed a strong interest in bush foods and the value of plants in human nutrition. His scientific integrity and passion for food as medicine shines throughout the book. Reading his book is an enjoyable journey through the history of chemical compositions; and why a plant's ecological system makes phytochemicals that can be used to promote health benefits.

The benefits of eating a variety of healthy foods and their relationship to good health is not necessarily a new topic. For decades, many books and information sources on healthy eating have not always been married with scientific knowledge or current technologies; they have been based on information available at the time, often anecdotal or lacking scientific foundations. Further, marketing strategies are often the basis of health information for the broad society, which can by nature often be biased and lack substantial scientific explanations or evidence. The analytical mind asks why these campaigns are allowed to be conducted in the first place, or who in the food industry was benefiting from these heavily funded initiatives. In the current era of social media featuring 'fake news', opinionative blogging and promotion by famous people of their eating routines, it is difficult to identify trustworthy sources or be confident in the science behind the public information. Contrastingly, Hippocrates and Avicenna wrote many historical texts long before the common era (BCE) and were regarded as great scientists of their time. They both outlined the importance of eating healthy foods and maintaining a balanced lifestyle, and many of their findings in these fields are still applicable today.

Paul Williams' book takes you on a journey through history, to explain the evolution of why we need to think about the foods we eat. It is not a narrative about any specific dietary advice, eating plans or calorie counting, all of which is made very clear. *Feast on Phytochemicals* is a book about rethinking the food basics and the chronic diseases associated with inflammatory markers in the body. He explains the scientific evidence of phytochemicals well and outlines why eating an array of colour on our plates, obtaining a variety of fresh foods and eating the required amount of fibre is important in our daily life. All the chapters in his book are scientifically current and pertinent topics for today.

The chapter on Australian Aboriginal and Torres Strait Islanders' bush foods will be of interest to anyone who lives in Australia or has an interest in ethnobotany. The study of bush foods is an emerging field, and it is becoming more common to find various products on the supermarket shelves. In the previous millennium, explorers and early settlers documented their gratitude for bush medicines that saved their lives, or at least helped them overcome illness or injury. Dr Williams describes the plants' demographics, traditional use and the phytochemical information available. The chapter is sure to appeal to the Society's own Professor Ray Specht, Life Member, who has shown an intense interest in Indigenous use of plants during his 70-year-long research career.

Dr Williams' ability to convey his scientific message in an easy-to-read manner will be enjoyed by many audiences and become an integral part of many people's libraries. He relays a strong message on the importance of food as a healer. The practical advice given throughout the book is backed by scientific evidence.

The book does not necessarily need to be read from front to back: the reader can enter at any chapter, in any order depending on initial interests and still follow the core messages; however, reading the book in its entirety will give perspective, as well as the many practical tips that seem so simple once they have been read. An example of a practical tip is that chopping garlic and letting it sit for a few minutes will activate the constituents needed for greater health benefits. The book really makes one think about what foods need to be put into the mouth to prevent chronic health conditions.

*Feast on Phytochemicals* is comprehensive. It has an easy-to-read glossary at the front which helps understand terms not already known to the reader. The diagrams and tables throughout are a quick reference to the information within. In each chapter the author reiterates a need to go back to food basics and reassess what goes into our mouths because what we eat affects our biochemistry. The bibliography is also comprehensively referenced.

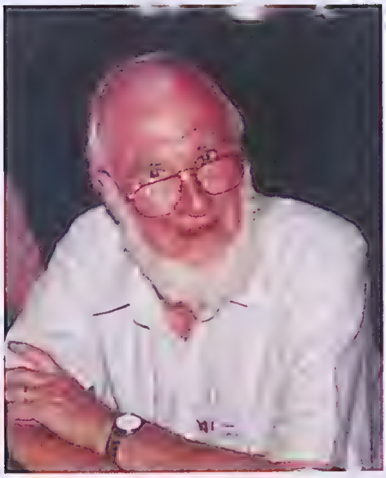
This book can be recommended as a university text for food science and nutrition students, as well as for a general audience of persons with an interest in food to enhance their health. It is scientifically detailed and is easy to read and comprehend.

REVIEWED BY NITA SHARP

*Feast on Phytochemicals* may be purchased from the book's website: https://phytochemicalfeast.com/

# OBITUARY FOR H. T. CLIFFORD, 1927–2019

## A Multiversed Generalist in Plant Sciences



Harold Trevor Clifford (hereafter Trevor) gained his primary degree in Geology and Botany at Melbourne University, subsequent to which he tutored in Botany at that university and took up a cadetship at the National Herbarium of Victoria. During this period he worked with Jim Willis on the mosses of Victoria (Clifford & Willis, 1951), and later on the mosses of Macquarie and Heard Islands (Clifford, 1953), from where he recorded his first fossil with Isabel Cookson (Clifford & Cookson, 1953). Many decades later he reinterpreted this specimen as the operculate seed of *Typha* (Clifford & Dettmann, 2000). He studied for his masters degree at Melbourne University on the biogeography of the Dandenong Ranges under the supervision of the Professor of Botany, John Stewart Turner (JST), and co-supervision of Maisie Fawcett (later Carr). Unable to determine the precise taxonomy of the eucalypt species he found there, he identified a 'hybrid swarm' for which he developed an explanatory model, subsequently published in the Nature journal *Heredity* (Clifford, 1954), collaborating on two other articles with F. E. Binet, a statistician from the CSIRO (Clifford & Binet, 1954; Binet et al., 1959). This became one of the themes of his research career. While in Melbourne he met R. A. Fisher, the famous statistician from the Rothamsted Experimental Station and later the University of Cambridge, UK, who was visiting at the time, as well as David Goodall, then a lecturer at the University doing his pioneering work on interspecific correlation. These were both influential connections for Trevor.

Fisher encouraged Trevor to continue his work on the hybridisation of species, and with the connections that JST was able to provide, he gained a scholarship to do his PhD on hybridisation in primroses at Durham University under David Valentine. After his PhD, and with a new family, he took a job in Ibadan, Nigeria, where he was a lecturer in Agricultural Botany from 1955–1958. He worked on problems related to grain storage, in particular breaking of dormancy and seed dispersal. This was perhaps the start of his major work on grasses and germination behaviour throughout the plant kingdom. In 1958 he took a position at the University of Queensland, where he stayed until his 'retirement' in 1992.

The next phase of his career was multi-faceted, each facet informing the other. His research work fell into four main strands: the taxonomy of monocots (especially grasses), numerical classification, evolutionary taxonomy, and hybridisation. The unifying principles across these were, as he said in his professorial lecture in 1985, 'Taxonomy, Tradition and Technology'. Taxonomy in broad terms was his main passion, with its ubiquitous application to almost every aspect of life: we name and classify things all the time, giving meaning to each. In doing so, traditions develop, which, although our knowledge and understanding may improve (stimulated by advances

in technology in particular), are often hard to shift. This passion revealed itself in his fascination with the linkages between 'things' across time and space, and the use of nomenclature to describe the nature of those 'things'. His love of discussion was enormous as he explored the world, bouncing ideas off people and, in doing so, probing concepts in his head, following this intellectual life with rigorous and diligent measurements and observations.

He brought his research interests and sense of curiosity into his academic life and teaching. The University of Queensland was a fairly young institution when he joined it, and he rose to the occasion and co-authored many books directed at students and the wider public. He ensured that plant identification keys were both accessible and understandable, thinking carefully about the audience. For example, in the *Vegetation of North Stradbroke Island* (Clifford & Specht, 1975) he started with obvious plant traits such as flower colour, leaf shape and texture, latex production and so on, to help the lay-user identify their plant. Apart from his notably engaging teaching style, he was a member of many committees, somewhat unusual for an academic in the days of the 'God-professor'. He mentored postgraduate students, his own and others, particularly through his enjoyment of challenging conversation, including memorable discussions around the joys of the Fibonacci series. His service to the University was sometimes serendipitous, such as when he 'provided' the material for the 'Avenue of Honour' in the Great Court. The gardeners needed trees and found his – apparently all uniformly identical – young plants from one of his eucalypt 'hybrid swarm' experiments and used them. The resulting trees varied wildly in shape at maturity, to Trevor's glee and the horror of the gardeners, and reminded many of Trevor for many decades to come.

Trevor was one of the early data scientists, initiating discussions in Brisbane on the new techniques of numerical classification, inviting Geoffrey Lance and Bill Williams, FRS, to participate in a seminar group at the University to further the field. This seminar group turned into a subject at the University (with Bill Stephenson, Professor of Zoology), a trans-disciplinary book (Clifford & Stephenson, 1975), and many applications of numerical analysis in his publications (e.g. Clifford & Williams, 1973, 1976, 1980; Clifford et al., 1969; Williams & Clifford, 1971; Williams et al., 1971a,b). This field has grown massively in importance as computing power and the discipline of data science has grown, and many of his students developed outstanding international careers benefitting from the foundation he gave them.

His work on evolutionary taxonomy took him to Denmark to work with Rolf Dahlgren, where he expanded his expertise on grasses to cover the whole of the monocots, becoming one of the foremost experts on these plants and producing many articles combining his interest in nomenclature, numerical classification and evolutionary taxonomy. Their joint work on family circumscription in the monocotyledons has had a profound and lasting influence well into the molecular age (Dahlgren et al., 1985). Dahlgren's taxonomic classification of flowering plants formed the foundation of the arrangement of many floras, such as the *Flora of New South Wales* (Harden, many volumes), and much of it still survives in the current Angiosperm Phylogeny Group classification of the flowering plants (Angiosperm Phylogeny Group, 2016). Trevor thought innovatively, and his *Nature* article with Rod Rogers and Mary Dettmann was an excellent example of this, even though it generated significant ire from some members of the botanical community at the time (Clifford et al., 1990); so much so, that at a subsequent dinner with Sir Ghillean Prance (then Director of the Royal Botanical Gardens, Kew) and his wife, Prance's wife commented upon meeting him: "You don't have horns!"

Trevor's palaeobotanical research was rekindled towards the end of his academic career at the University of Queensland when he collaborated with Mary Dettmann in studies of fossil ferns and their spores. At retirement he continued palaeobotanical research at the Queensland Museum on fossil bryophytes, early ferns (some ~350 million years old), conifers and angiosperms, including 95–100 myo, anatomically preserved flowers and a range of extinct plants from Queensland sediments. During his retirement, he and his collaborators collectively "have done more to document the northern Australian fossil macroflora than any other research group" (pers. comm. Andrew Rozefelds). At the time of his death, Trevor had a paper in press describing one of the youngest fossil horsetails known from Australia, extending their persistence here by about 50 million years.

Concurrent with the research at the Queensland Museum, Trevor was an Honorary Associate at the Queensland Herbarium, and took an active interest in botanical matters at the Brisbane Botanic Gardens (Mt Coot-tha). His advice was frequently sought on botanical matters in a wide range of areas. For example, he freely gave of his knowledge in the planning of the handbook *Wild Plants of Greater*

*Brisbane* published by the Queensland Museum, and to authors on botanical aspects in several other fields, for example, *A Doctor in the Garden* by John Pearn (2001) and *The Flower Chain; The Early Discovery of Australian Garden Plants* by Jill, Duchess of Hamilton (1998).

Trevor was a great collaborator, hard-working, diligent, exploratory, generous, intellectually critical but kind. He enjoyed the spoonerism of his name to 'Clever Triffid' – ironically predating Wyndham's 1952 book [*The Day of the Triffids*] – regarding it, quite rightly, as an expression of respect and fondness. Discussing his Emeritus status in his self-deprecating way, he drew attention to the definition of emeritus in Stearn (1992), 'that [which] has become unfit for service, worn out, burned out extinguished (Lewis and Short): applied by Ovid to horses, by modern universities to retired professors'.

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# OBITUARY FOR Dr BEN LAWSON, 28 AUGUST 1976 – 23 JUNE 2019

Dr Ben Eric Lawson, September 2006, age 30.

Dr Ben Eric Lawson [Ben] converted an early interest in hydroponics and agriculture into a lifelong involvement in citizen science, openly sharing his knowledge and expertise in the natural world with others. Over the past decade he was a vital member of The Royal Society of Queensland Council, working in particular to expand the reach of the annual *Proceedings* more widely in society.

## RESEARCH CAREER

Ben completed a Bachelor of Science at the University of Queensland with majors in botany and ecology. His Honours project focused on predicting the distribution of two Weeds of National Significance (*Anredera cordifolia* and *Schinus terebinthifolius*). He soon commenced research into vegetation mapping processes and their implications for conservation planning in Queensland. He was awarded a PhD in Conservation Planning in 2007 for his thesis entitled *The utility of site-based datasets and regional ecosystem mapping for biodiversity conservation in the South-east Queensland Bioregion: Past, present, future.* A postdoctoral research position followed, contributing to mapping of the distribution of insect agents for the control of mimosa and lantana.

Ben co-authored a number of papers on weeds, including a chapter on *Anredera cordifolia* in the *Biology of Australian Weeds* 2009 and a climate prediction of buffel grass (*Cenchrus ciliaris*) published in *Plant Protection Quarterly* 2004. Other papers were generated out of his PhD, including "Relating spatial and temporal patterns in floristics with vegetation mapping: an example from Fraser Island, South-East Queensland, Australia" published in *Pacific Conservation Biology* 2006, "Delving into the Datasets I and II" published in *Australasian Journal of Environmental Management* 2006 and "Are regional ecosystems compatible with floristic heterogeneity? A case study from Toohey Forest, south-east Queensland, Australia" published in *Pacific Conservation Biology* 2007.

He presented his PhD research in stages at the annual Ecological Society of Australia conferences in Perth, Adelaide and Brisbane, and at the International Association for Landscape Ecology in Darwin, Australia (2003) and Wageningen, The Netherlands (2007). At one such conference, a discussion about databases, data, and long-term ecological research began a lasting relationship with Dr Jean-Marc Hero and Dr Bill Magnusson. Ben became involved in their Planned Programme for Biodiversity Monitoring (PPBio), including collaboration and excursions to Karawatha Forest in Brisbane (with Griffith University) and in the Amazon. Many papers were generated out of these PPBio interactions, some of which appeared in the co-authored book chapter "Multi-taxa Surveys: Integrating Ecosystem Processes and User Demands" in the book *Applied Ecology and Human Dimensions in Biological Conservation* published in 2014.

In 2008–2009 he organised and led a working group of some 14 Australian and international researchers aiming to develop a framework for rendering existing ecological classifications more fit for purpose. The workshop resulted in one peer-reviewed science publication and an invited symposium session at the 2009 conference of the International Association of Landscape Ecology. Senior researchers reportedly noted that it was the most well-organised and productive working group with which they had been involved, despite the diverging views and interests of the participants.

In summary, Ben authored or co-authored:

- 12 peer-reviewed publications in Australian and international scientific journals
- 9 conference presentations at Australian and international scientific conferences
- 1 book chapter
- 1 book on biodiversity monitoring
- 4 review articles of science-based literature.

## EMPLOYMENT

Ben's first government role was in the Queensland Department of Natural Resources and Mines (DNRM), using his undergraduate skills to develop predictive mapping for a number of Weeds of National Significance. After completing his doctorate, he worked briefly at Brisbane City Council before moving back to DNRM where he revelled in translating the science into policy or, where the policy had no science in it, reversing the trend. Ben began in his familiar territory of vegetation management, before branching out to work in land valuations, and then strategic cropping land. It was Ben's scientific mind which devised the original criteria, and his policy mind that enabled him to negotiate effectively with all the stakeholder groups – including both the mining and farming sectors, as well as external consultants, departmental scientists, policy writers and legislation drafters. As a symbol of their respect for his work, stakeholders presented Ben with an hourglass, set in a sandalwood frame. The hourglass represented the fact that time had been about to run out, while a stainless steel bar set in the sandalwood marked the solid 'line in the sand' that was drawn by the Strategic Cropping Land policy, protecting premium farmland from unnecessary mining.

Living with muscular dystrophy did not prevent Ben from travelling or getting out into the natural world to pursue his personal, professional and academic interests. Ben participated in field trips in a wide variety of environments and landscapes, ranging from central Queensland to the Amazon Basin in Brazil on a trip associated with the National Institute of Amazonian Research in 2010.

Ben was a director on the board of Spinal Life Australia, an organisation providing advocacy, services and support to those with spinal cord injuries, and a former board member of the disability support organisation CODA South. He applied his life experience to improve cultural and sporting centre accessibility, including Suncorp Stadium, the 'Gabba and the Schonell Theatre at his alma mater, the University of Queensland. He also became a campaigner for bus safety for wheelchair users in South East Queensland and worked closely with TransLink to improve fare gate accessibility. From August 2008 to October 2009 he was a community representative to a forum "Progressing Inclusion of People with Disability in Business" convened by the Parliamentary Secretary for Disabilities and Children's Services in Melbourne.

## PASSION FOR CITIZEN SCIENCE PROJECTS

Ben had a love of data and a belief in the community's ability to gather and share it, both faster and more comprehensively than traditional approaches to research. Ben's input included regular *eBird* counts, seasonal pollinator counts, responding to a call for Macadamia DNA (sending off bits of his backyard macadamia tree in the name of science), posting natural history snippets on Twitter, and contributions to the *iNaturalist* online community. Indeed, in the 18 months after joining *iNaturalist*, Ben uploaded more than 388 observations of 160 different species, primarily from his own back yard. More impressively, he reviewed and identified 18,298 records lodged by others. Ben delighted in the opportunities for armchair birdwatching, botany and entomology that *iNaturalist* offered him once travel became tiring and cumbersome.

He had a range of home research projects, many of which had their origins in tea-breaks in his own back yard, armed with a keen eye and a GoPro. These included observations of fig bird feeding habits on *Archontophoenix* spp; species richness of pollinators on *Hibbertia scandens* and *Wodyetia bifurcata*; and communal habits of supposedly solitary ground-dwelling bee and wasp species.

## DEDICATION TO THE SOCIETY

Ben commenced his involvement in The Royal Society of Queensland in 2006 while still a PhD candidate.

His contribution as a committee member and Secretary continued throughout his working life until a handover of his roles in 2017. He tirelessly assisted the small Council in keeping the Society active and played an important role in the formation of the Queensland Science Network.

One notable contribution was the digitisation of the *Proceedings* and other Society records. What started with Ben's willingness to undertake minor administrative duties and assist with publication mailouts from his home progressed and expanded until volumes of the *Proceedings* and paperwork filled his home study. While at home with his young daughter, Ben devised a scanning project to digitise these volumes and free up space, not just in the study, but in the Society's substantial historical paper collection that was being re-catalogued by the Queensland Museum Library. Ben sourced and managed a grant culminating in a digitised and searchable collection of the Society's *Proceedings* dating back to 1884. The project also stored original meeting notes electronically and saw the most important documents lodged in the State Library Archives. The successful tenderer, archivist company Avantix, created a new web presence and search engine for the Society, in recognition of the importance of the collection.

On 13 June 2019, His Excellency the Governor of Queensland invested Ben with Honorary Life Membership of The Royal Society of Queensland, at a reception at Government House in recognition of his dedication.

Through his passion, intelligence, generosity and integrity, Ben brought the best out of other people, improving the world around him in the process.

Ben is survived by his wife Sara and daughter Grace.

AUTHORS

Cate Melzer, Vice-President 2000–2014, Secretary 2004–2007, Councillor 2014–2015, Life Member

Craig Walton, President 2004–2013

# ROYAL SOCIETY OF QUEENSLAND ANNUAL REPORT 2018–2019

## OVERVIEW

This report covers the period from 11 October 2018 to 15 November 2019. The Society has again had an active year, with several inspiring events as well as timely publication of our journal.

In summary, the Society remains in excellent intellectual health but precarious financial health. During the year it made a significant contribution to outreach of science with its Rangelands initiative and, in so doing, confirmed a role in brokering the translation of science into policy. Repeatedly, the Society's officers questioned whether any other organisation, government or otherwise, was in a better position to champion a fresh approach to managing the semi-arid pastoral lands, and repeatedly came to the same conclusion: that no other body had the mandate, the necessary grounding in the natural and social sciences, and the independence from business-as-usual market economic orthodoxy.

It remained on the fringes of the climate debate, not through any intellectual timidity, but because many expert and well-resourced entities were already active.

During the year it strengthened its administrative team, which has allowed the workload of managing the Society's affairs to be shared and extended the capacity of the Council. Membership numbers have increased steadily during the year.

Council is proud that during the year it has again been able to publish first-rate material in its annual *Proceedings of The Royal Society of Queensland*. Volume 123 included five substantive scientific papers. In a demonstration of intellectual vigour and administrative optimism, Council readily agreed to support another four Special Issues of the *Proceedings*, in addition to the regular issue in 2019–2020.

We lost one of our most eminent Life Members in May, with the passing away of Emeritus Professor Trevor Clifford OAM.

Then the highlight and the low point of the year occurred within 10 days of each other in June. On 13 June, our Patron, His Excellency the Governor of Queensland, launched the Queensland Science Network at a reception in Government House and invested two new Honorary Life Members, Dr Ben Lawson and Ms Cate Melzer. Only 10 days later, Ben Lawson – our former Secretary and Treasurer – passed away. At the date of compiling this report, the Society is negotiating some form of permanent memorial to his intellect, his character and his dedication to the public interest.

## CORPORATE AFFAIRS

During the year the administrative capacity of the Society strengthened considerably, with the appointment part-time (average 2–3 hours per week) of Mrs Pam Lauder as Administration Coordinator, and John Tennock as Webmaster for both the Society's website and the Queensland Science Network website; and the agreement of James Hansen to serve as Secretary, and Dr Joseph McDowall to serve as Treasurer. Newsletter Editor Dr Anne-Marie Smit and Membership Coordinator Tony Van Der Ark round out the administration team.

### *Royal Society of Queensland Council*

The Council elected at the Annual General Meeting comprised Angela Arthington, Paul Bell as Editor, Geoff Edwards as President, Andy Grodecki, James Hansen, Ross Hynes, Joseph McDowall, Revel Pointon, and Craig Walton as Immediate Past President.

Face-to-face meetings of Council were held on 1 March, 19 September and 12 November 2019. In each case, every Council member either attended or gave an apology. The vast bulk of issues are debated via email traffic.

Early in the new Council year, Dr Diogenes Antille offered to serve as Editor and Dr Paul Bell stood aside. Ross Hynes and Revel Pointon offered to serve as Assistant Editors. On 6 October, Revel Pointon took over as Acting Editor. We thank Diogenes Antille, Paul Bell, Ross Hynes and Revel Pointon for their collective endeavours in keeping the journal procedures flowing.

### *Finances*

The Society continues to draw down its accumulated reserves in order to fund its current activities. The officers have been unsuccessful in securing significant general-purpose sponsorship. There have, however, been several highly valued donations from members, including a couple of substantial donations to the Research Fund; and a grant of $9500 from the Queensland Government towards the cost of the Rangelands Policy Dialogue in June.

*Library*

During the year Meg Lloyd, our Honorary Librarian, retired from her post at Queensland Museum; and Shannon Robinson, the Museum's Librarian, accepted an invitation to serve in that role. New members may not be aware that they have free access to the Society's library of some 20,000 volumes housed at the Queensland Museum.

*Membership roll*

At 8 November 2019, the Society had 136 paid-up members, with others due for renewal. This is 40 more than at about the same time last year, a remarkable increase. There are six Honorary Life Members: Dr A. Bailey, Dr J. S. Jell, Dr J. O'Hagan, Ms C. Melzer, Prof. C. Rose and Prof. R Specht.

Member Tony Van Der Ark has continued to maintain the Membership Roll. The role includes contacting those members whose memberships have expired, to clarify their intentions, and to guide them in renewing online.

A memorial service for long-standing member and Life Member Emeritus Professor Trevor Clifford OAM was held on 13 May at Christ Church St Lucia after a rapid and steep decline in his health. His wife, Mrs Gillian Clifford, passed away not two months later. A memorial service for member and Life Member Dr Ben Lawson was held on 2 July at Emmanuel College St Lucia. The Society was represented at both events. Our condolences are expressed to the family of each of these wonderful people.

*Royal Society of Queensland Annual General Meeting – 29 November 2018*

The Annual General Meeting of the Society was held in the Community Meeting Room of the Brisbane City Council, Brisbane Square, Adelaide Street.

PUBLICATIONS

*Proceedings of The Royal Society of Queensland*

Volume 123, produced by former editor Dr Barry Pollock, appeared on time at the end of 2018. Volume 124 is now in preparation.

Four Special Issues are also in various stages of preparation: Volume 125, edited by Prof. Roger Kitching, on the Eungella rainforests; volume 126 on the springs of the Great Artesian Basin, co-edited by Dr Rene Rossini with Prof. Angela Arthington; volume 127 on preventative health, by Dr Joseph McDowall; and volume 128 on stewardship of the Rangelands, co-edited by Paul Sattler and Dr Ross Hynes.

Grants of \$9000 and \$15,000 have been gratefully received from the Queensland Department of Natural Resources, Mines and Energy; and the federal Department of Agriculture and Water, respectively, to print the Special Issue on the springs of the GAB. The federal grant will allow the Society to host a session at the November international groundwater conference in Brisbane.

Grants of \$2000 from Griffith University, \$1000 from Reef Catchments and \$500 from a private philanthropist have been received towards the cost of publishing the Eungella rainforests Special Issue. We are very grateful for the generosity of these sponsors.

The long-standing value of the Society's role in publishing general science was highlighted in an article in volume 123 by member Col Lynam reporting on a handwritten entry in the minute book of the Queensland Philosophical Society of 1865–1883, forerunner of The Royal Society of Queensland. The minute book records an earthquake west of Townsville in January 1879. "The discovery of this 4-page descriptive essay is of note because the earthquake's concurrence is not listed in any of the definitive Australian or international catalogues." The author believes it to have been the "first scientifically documented macroseismic study of an earthquake with an epicentre in Queensland".

*Members' Newsletters*

Fifteen Newsletters (including intermediate Notifications) were produced during the AGM–AGM year, against a target of monthly. Dr Anne-Marie Smit continued to edit the Newsletters, an important service in keeping a strong network amongst the membership. These Newsletters are privileged to members. Our Webmaster John Tennock is progressively uploading previous Newsletters to a members-only section of the website.

*Members' publications*

Apart from journal articles, four substantial book-length works were published by members in their own right during the AGM–AGM year:

*The mysteries of Frederick Strange, naturalist* / Patrick Comben
*Feast on Phytochemicals* / Paul Williams
*Tropical ecosystems in Australia: responses to a changing world* / Dilwyn Griffiths
*Living at a Lighthouse* e-book / Ron and Yvonne Turner.

Although the Society takes no credit for these works, we hope to strengthen the intellectual environment in

which our members feel confident to put their knowledge into print. The Society will arrange publicity for these works.

## EVENTS

*Preventative health – 20 February*

The third in a series of three brainstorm-type workshops sponsored by PricewaterhouseCoopers was held on health in Indigenous communities, on 20 February 2019. Keynote speaker was Dr Damien Howard, Psychologist, Phoenix Consulting Darwin (by video link), on institutional silos as an impediment to progress. Panellists were:

- Dr Wendy Laupu RN, on strategies to preventing mental disorders;
- Dr Joseph McDowall, CREATE Foundation, on reasons for the over-representation of Indigenous young people in out-of-home care;
- Dr Geoff Edwards, President, Royal Society of Queensland, on "feasible paths" to well-being.
- Local Indigenous identity Dr Janet Hammill gave an acknowledgement of country.

The Society records with gratitude the willingness of the speakers who gave generously of their time to present. Dr Laupu travelled from North Queensland at her own expense to deliver.

The preparation of a model of preventative health, bridging disciplines, sectors, levels of government and partisan ideologies, is an unfulfilled commitment of the Society and the President. Progress has been slow because of the work occasioned by the Rangelands initiative.

*World Science Festival, 23, 24 March*

Our Membership Coordinator, Tony Van Der Ark, with the active assistance of several members, notched up a considerable success for the Society and its Queensland Science Network through organising and populating a booth at the World Science Festival on 23, 24 March with interesting activities and materials. Special thanks to Tony, his son and member Harry Van Der Ark, Council members James Hansen and Andy Grodecki, and members Robert Whyte, Anne Jones and Anne Marie Smit. The booth was very popular, and the organisers expressed a commitment to repeat the exercise next year.

*Launch of Queensland Science Network, 13 June*

Our Patron, His Excellency the Governor of Queensland, graciously hosted a reception at Government House Paddington to invest two new Life Members, Dr Ben Lawson and Cate Melzer, and to launch the new website of the Queensland Science Network. In so doing, he officially launched the Network itself. At the reception he presented certificates to Tony Van Der Ark and his son Harry for their sterling work in organising the first official event conducted in the name of the Queensland Science Network, the booth at the World Science Festival.

Attendance was by invitation, and a good selection of representatives of member bodies made for a memorable occasion.

*Rangelands Policy Dialogue, 1,2 July*

Following the May 2018 presentation on stewardship incentives, the Society forged a collaboration with AgForce and NRM regions to present a two-day workshop to lay a foundation for Rangelands policy in the light of climate change and enduring unprofitability, which make business as usual in the pastoral zone untenable. The event was deferred from May, when advice was received from the Department of Environment and Science that they would be prepared to grant $9500 on a no-strings-attached basis to support the Dialogue. AgForce contributed $1990 towards the cost of the auditorium. These sums approximately covered the costs.

Attendance was loosely by invitation, and the event was strongly supported by members of the Society. Some 120 people attended. The Society is grateful to the presenters, "carrier pigeons" who conveyed successive reports to member Des Hoban in an adjoining room compiling notes, to member John Brisbin who excelled as Master of Ceremonies, and to Pam Lauder who organised the logistics. One of the intended outputs – A Rangelands Declaration – representing a consensus of the Dialogue and endorsed by the three co-organising bodies – was published on 20 August.

## COMMENTARY

In mid-December 2018, *Queensland Country Life* invited the President to submit a regular column under its "View from the Paddock" series of opinion pieces. Columns were published on 7 February, 18 April, 27 June, 5 September and 14 November 2019. The newspaper also published a supernumerary column on 17 October defending the integrity of scientific publication. The Society is grateful to the Editor for allowing this opportunity to present opinions on behalf of Queensland's scientists. All articles were printed without editorial amendment.

The online public policy newsletter *The Mandarin* published three opinion pieces from the President during the period under review:

- 25 October 2018, "Rural policy needs more than a one-day drought summit";
- 12 March 2019, "Economic profit impossible if the Murray-Darling keeps eroding";
- 12 July 2019, "Publicly funded research is the source of scientific knowledge economy" building upon research by member David Marlow on the subject of Gravestones – credible scientific bodies that have been abolished by governments despite success.

All draft opinion pieces, and indeed any public statements by the President on behalf of the Society, are cleared with Council beforehand.

## RSQ AND QSN WEBSITES

The major advance during the year was the offer by John Tennock to serve as voluntary Webmaster. When John also offered to redevelop the QSN website in WordPress instead of the more demanding Drupal, Council offered a small honorarium. Both websites are now operating smoothly. Visitation to the QSN website is still low, but the potential for this to serve as the major portal into Queensland citizen science is very large. The layout of the reconstructed website is now intuitive, with a rapidly expanding archive of interesting materials.

As a general policy, the Society's website is reserved for activities and publications by the Society and its members. The QSN website presents a wider range of general science activities and materials, largely (but not rigidly) confined to the activities of its member groups. The QSN website includes links to some other sites of general science interest, such as the Events Calendar of *Inspiring Australia Queensland*.

An article in the October Members' Newsletter itemised the vehicles that the Society offers to its members to publish knowledge that they generate:

- a snippet in the Newsletter;
- an article, report or memoir under Members' Interests on our website;
- an article on the QSN website in a range of formats; or
- a peer-reviewed article in our *Proceedings*.

To that can be added a draft of an opinion piece for issue by the President in the Society's name.

Five members took advantage during the year of the opportunity to open a page for their field of interest: Phil Andrews, Prof. T. Clifford, Elwyn Hegarty, David Marlow and Ron Turner. This opportunity is available free of charge to all members.

The digital membership roll has operated smoothly during the year. An encouraging expression of confidence in the Society's work program is that many members have renewed for two or three years. Payments for new memberships and renewals that are made via cheque or direct bank deposit (a minority) are transferred manually. Members are reminded that if they make payment by direct bank deposit, they must identify the source at the time by filling in the "Reference" field, or the payment cannot be traced.

## RESEARCH FUND

Consistent with the commitment in 2018 to fund grants in three successive years, a second round of grants was announced, and closed on 31 July. The Society congratulates Dr Michaela Blyton of the University of Queensland on winning the first award for a project on koala microbiomes; and Dr Bonnie Quigley, University of the Sunshine Coast, for a project on koala retrovirus infection. There was a strong field of contenders, and Council approved of publishing teasers for some runners-up in the hope that they might attract sponsorship.

The second award was possible because the Australian Koala Foundation agreed to sponsor the first award. This enabled the Society to make a second grant, which coincidentally was also on a koala theme. We express our gratitude to the Foundation and to three anonymous reviewers.

## ROYAL SOCIETIES OF AUSTRALIA

A significant step in Australia's science outreach was taken in September when Council approved joining the Royal Societies of Australia, along with our New South Wales counterpart. This followed negotiation between New South Wales and the Australian Academy of Science that confirmed that the Academy would welcome the reinvigoration of the RSA, with a mission to focus on science outreach as distinct from elite science. The Academy is providing office space and a part-time coordinator. John Hardie, principal of RSA and a member of our own Society, was receptive to recommendations for amendments to the draft constitution.

It is proposed that the RSA will organise a significant event on "stewardship of country" in the first half of 2020, probably in Canberra to secure a national audience.

## FINAL WORDS

The steady rise in membership numbers during the year suggests that Council's policy of strengthening the Society through activities has been successful. Particularly welcome is the broad scope of fields of interest of the new members.

During the year, Council repeatedly revisited the question of what distinctive role it can offer in a fractured external policy environment that seems to place low value on scientific authority. This question repeatedly came to the fore during its deliberations over Rangelands science and policy; and in particular when AgForce, our co-organiser, took a public pugnacious approach towards the Queensland Government, and in particular towards the science of the Great Barrier Reef.

Council has repeatedly confirmed the view that the Society has a unique role, as it can offer all of the following to Queensland public debate:

- cross-disciplinary, not wedded to any single knowledge specialty;
- non-partisan, not associated with any political faction;
- non-conflicted, not beholden to any commercial interests or dependent upon funding from government or any other sponsor;
- not limited in its examination of issues by economic or any other orthodoxy.

These features of the Society's profile give it confidence to continue to offer its capacity for reflection and analysis on issues such as Rangelands. As for the previous year, this is hampered by its inability to tap into a source of funding to allow it to underpin the work of its volunteers with executive capability.

If anything, the policy environment seems to have deteriorated during the year, and the lack of scientific literacy by participants in public debates, especially the climate debate, is more obvious. More than ever, it appears that it is incumbent upon scientists to reach out into the policy arena to bridge the shortfall.

Council thanks all those members who have attended events, have communicated by email and telephone, and have contributed to upholding the value of independent knowledge. We appeal to all members to renew their affiliation when the time arises.

Date: 15 November 2019

## CONTENTS